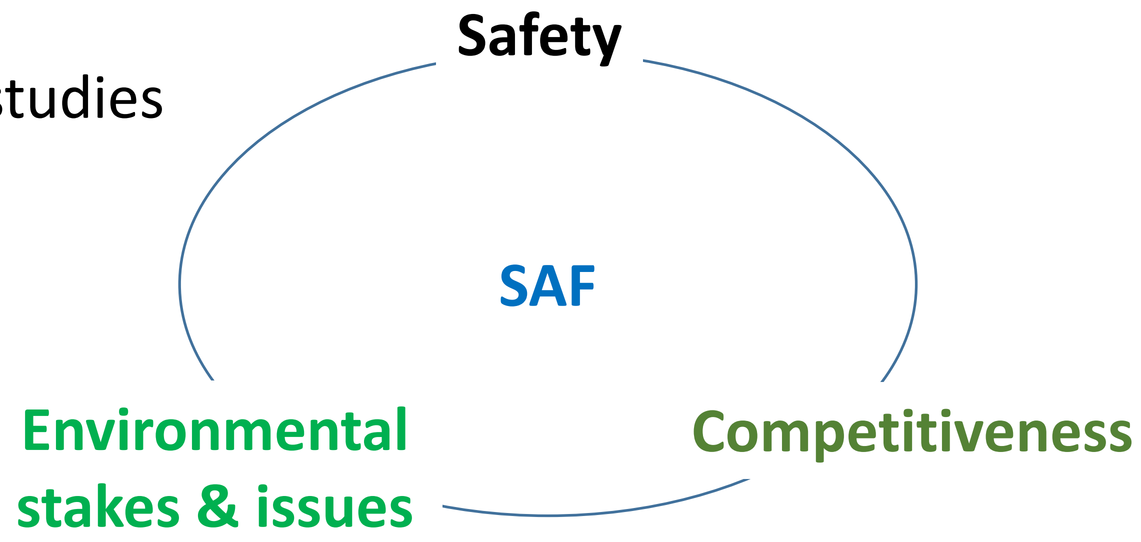
CHALLENGES AND OPPORTUNITIES

100% SAF Operations for Business Aviation

EASA Bizjets workshop 2025 Jan. 21-22

Challenges and opportunities
SAF Operations for Business Aviation

- The Falcon Family
- Increasing environmental stakes & issues
- Contrails & non-CO_2 emissions : background & studies
- Preparing tomorrow’s flights
- 100% drop-in SAF/SATF questions
- Conclusion



The Falcon family

Falcon 10X

Wingspan: 33,6 m
Length: 33,4 m
Height: 8,4 m
Range: 7,500 nm (13,890 km)

New York → Shanghai
Los Angeles → Sydney
Paris → Santiago

Falcon 8X

Wingspan: 26.3 m
Length: 24.5 m
Height: 7.9 m
Range: 6,450 nm (11,945 km)
Beijing → New York
Paris → Singapore
São Paulo → Moscow

Falcon 6X

Wingspan: 25.9 m
Length: 25.7 m
Height: 7.5 m
Range: 5,500 nm (10,186 km)
Los Angeles → Geneva
Beijing → San Francisco
Moscow → Singapore

Falcon 900LX

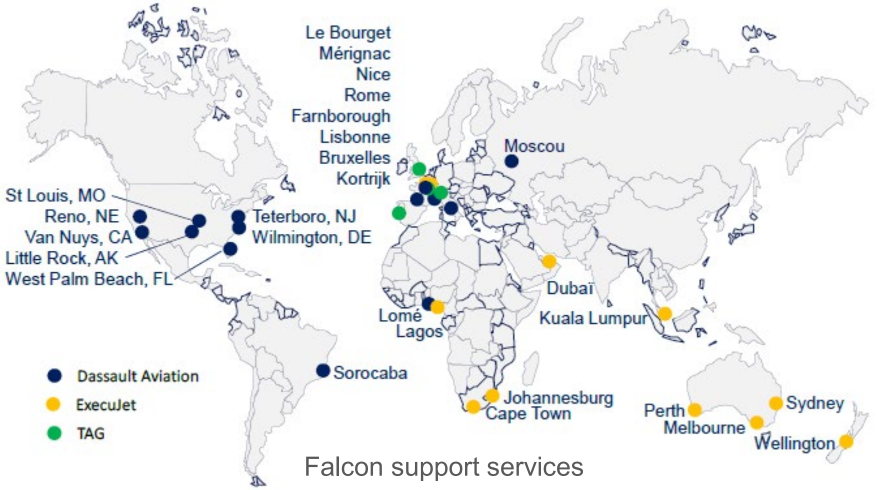
Wingspan: 21.4 m
Length: 20.2 m
Height: 7.7 m
Range: 4,750 nm (8,800 km)
Mumbai → London City Airport
Geneva → New York
Hong Kong → Sidney

Falcon 2000LXS

Wingspan: 21.4 m
Length: 20.2 m
Height: 7.1 m
Range: 4,000 nm (7,400 km)
Dubai → London City Airport
New York → Copenhagen
Singapore → Dubai

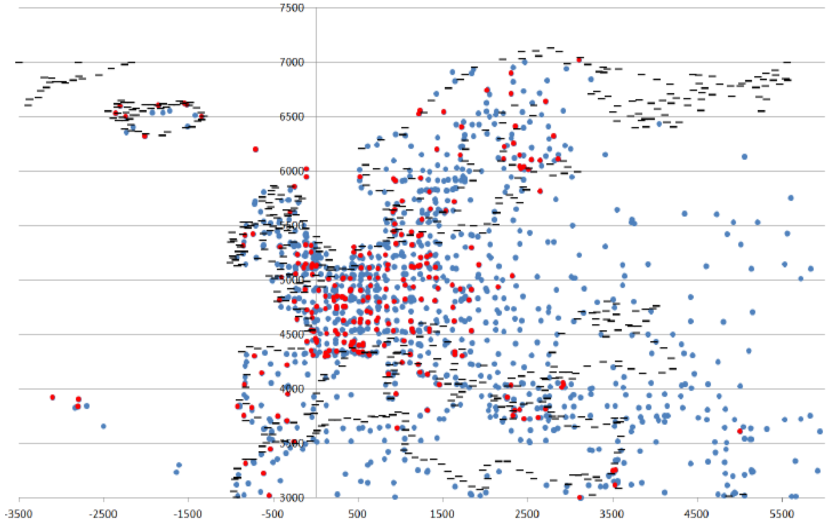
The Falcon family : « Take away »

- More than 1200 Falcon operators in more than 80 countries for ~ 2100 aircraft in service



Falcon support services

- 10 times more airfields accessible to business jets than to commercial liners, for 50 times fewer flight hours per year
- Long range aircraft capable of more than 10 hours flights
- Combining efficiency and flexibility, fulfilling the needs for travel over short jumps to very long distances
- Flying at higher altitudes (FL 410 to FL 510) above liners
- A very high level of demand on operational availability
- Customers buying new aircraft types show increasing concerns about environmental impact criteria



Small fleets, flying everywhere, at all times, with limited external support

DASSAULT AVIATION

Increasing environmental stakes & issues in Aviation

- Sustainable Aviation Fuel to be generalized
  - Falcon family meet ASTM D1655 technical specification
  - All in-production Falcon models are certified to fly with SAF/kerosene blends up to 50% v/v

In 2023, **413** Corporate Falcon flights using 30% SAF blends ~**700** tons of CO_2 saving over the year

- Falcon F10X "100% SAF drop-in" natively compatible upon EIS
- General climate commitments
- Industrial & In service emissions reduction
- Non CO_2 radiative forcing & energy sobriety
- Preparing tomorrow's flights

On February 2024, partnership between Groupe ADP and Dassault Aviation

Climate commitments = Major topic for Dassault Aviation

Contrails & non-CO_2 emissions : background & studies

- Persistent contrails : 2 conditions that occur concurrently

  1. The Contrail is formed under specific conditions
  2. The Contrail does not disappear (no evaporation) **<u>if and only if</u>** **<u>Ice/Water Saturated Atmosphere</u>**

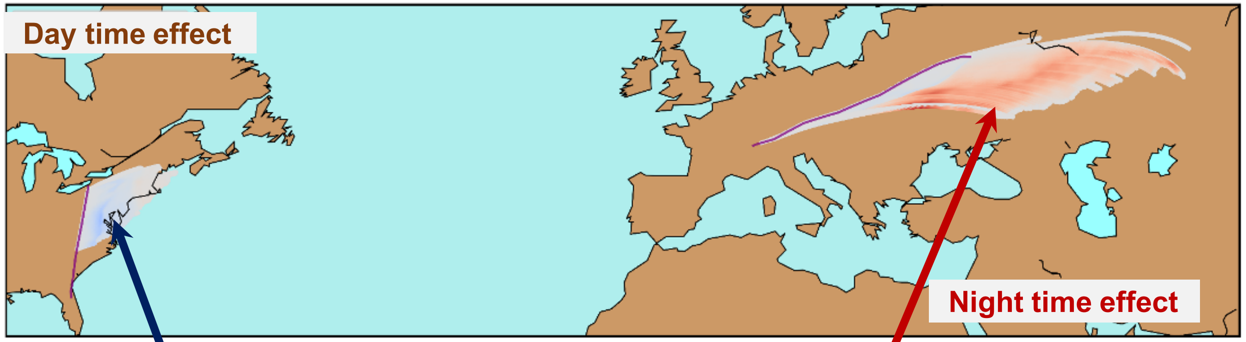
3 hours later

- The climate impact of contrails & non-CO_2 emissions is still a research subject
- Further work in progress to **mitigate assessment uncertainties and consolidate predictions**

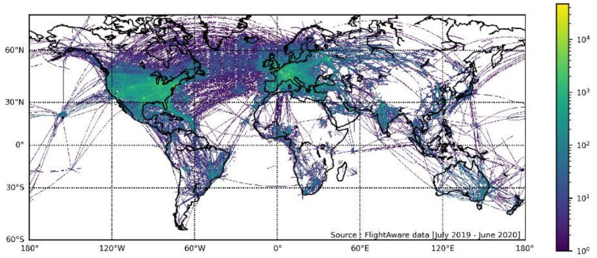
Contrails & non-CO_2 emissions : background & studies

Recent statistics show that the climate impact of the contrail of one flight may be « high enough » to motivate a trajectory adaptation, with detour, to avoid this contrail.

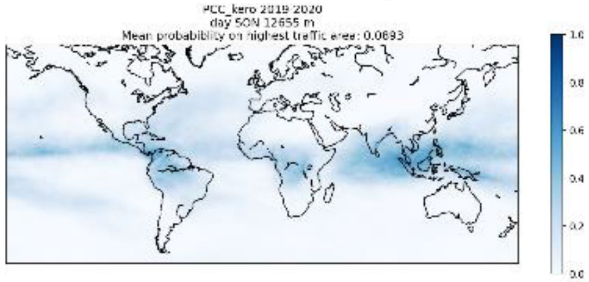
- **<u>2% to 9%</u>** of flights are responsible for **<u>80% to 100%</u>** of the non-CO_2 climate impact.
- Optimizing fuel, selection-trajectories & departure time can be very efficient.
- A research subject bringing **more opportunities** for General Aviation



colding effect contrails & warming effect contrails



Ex: Falcon fleet trajectory 2019-2020 (~95000 flights)



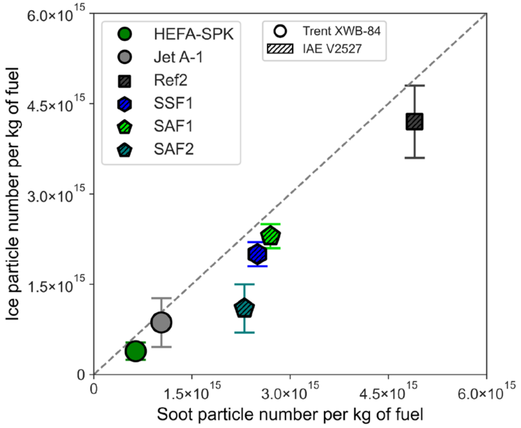
Persistent contrails (statistics)

Persistent contrails, and contrails, a recurring concern for Dassault Aviation

Contrails & non-CO2 emissions: Potential reduction with SATF

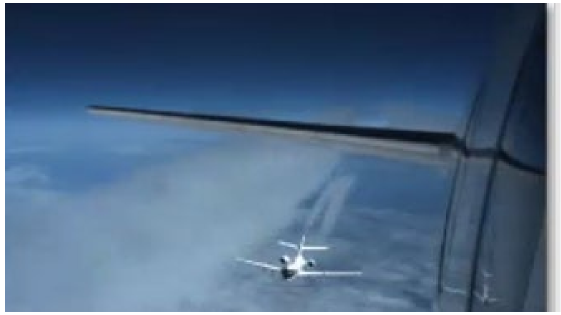
- SATF = Synthetic Aviation Turbine Fuel **vs** SAF = Sustainable Aviation Fuel
- SATF specification should contain a low rate of aromatics which should reduce engine particles emission
- Two major questions have to be considered:
    1. Emission reduction trend consolidation and climate impact benefit
    2. SATF production/usage variability

- Dassault Aviation is an important contributor on R&I projects to demonstrate benefits of SATF on aviation



<u>100 % HEFA-SPK vs Jet A-1:</u>
Clear soot particle reduction
Clear ice particle reduction

© Voigt et al., *Cleaner burning aviation fuels can reduce contrail cloudiness,* Communications Earth & Environment (2021)2:114



DASSAULT AVIATION

Preparing tomorrow's flights

- Development of an innovative and evolutive plan tool optimizing flight plans
- Allows to reduce CO2 emissions by selecting the most fuel-efficient route, while taking into account all other flight plan constraints
- New capabilities for non CO2 effects + CO2 emissions (+ noise flight optimisation)

Offering CO2 + non CO2 optimisation capabilities for each type of Falcon

Roadmap to 100% SATF Drop-in specification Dassault Aviation position (1/3)

- The ASTM D1655 Jet A/Jet A1 specification is not providing completness regarding the fuel properties required to ensure the fuel is safe enough to be integrated within the aircraft.

- The 100% « Drop-in » specification is a new approach:
  - No aircraft testing on full representative fuel batches
  - Fit-for-purpose properties: not controled directly by the ASTM D4054 (as previously) but required to ensure safe operation on aircraft regarding fuel and propulsion systems

New fuel validation process with associated uncertainties

Roadmap to 100% SATF Drop-in specification Dassault Aviation position (2/3)

- The current proposed SATF « drop-in » specification puts under control numerous properties by dedicated limits already shared to OEMs.
- Dassault Aviation performed a dedicated study taking into account lessons learned, fuel system and propulsion experts review and analysis to evaluate the potential impact of each characteristics on the operability, aircraft performances in respect of certification rules to maintain safe operation.
- The mandatory 20 properties of the proposed 100% drop-in specification are not sufficient to demonstrate all SATF are within the Jet A / Jet A1 experience.
- Additional properties to the already verified ones that are identified in the SATF research report should request a particular control process in the proposed drop-in specification shared with OEMs.

Roadmap to 100% SATF Drop-in specification Dassault Aviation position (3/3)

- List of properties to be covered by a particular control process (adressed or not) in the 100% drop-in specification which could have potential certification impact:

Properties	Certification requirements	CS-25 impact*	CS-E impact*
Auto ignition temperature**	CS 25.981 Fuel Tank Explosion prevention	X	
Permittivity**	CS 25.1305 fuel indication systems	X	
Density = f(T°)	CS 25.903 Engines	X	
Icing	CS-E 470 Contaminated Fuel	X	X
V/L ratio	CS-E 660 Fuel Pressure and Temperature	X	X
Specific heat**	CS 25.981 Fuel Tank Explosion prevention	X	
Viscosity**	CS 25.903 Engines	X	
Minimum Ignition Energy **	CS 25.981 Fuel Tank Explosion prevention	X	
Flash point dispersion**			

*: potential **: not monitored/verified in the future specification

EASA position and orientation required

Roadmap to 100% SATF Drop-in specification Summary

- Missing justification : see previous slides
  - Some fuel properties are linked to certification requirements. Aviation industry to demonstrate to certification authorities the requirement compliance when using 100% SAF drop in.
  - Additional data/justifications and possibly amendments to the specification may be necessary.
- Operation and maintenance :
  - Possible range impact to address
  - Schedule maintenance to adapt (example : seals inspections)
  - Engine non CO2 emission regulation ?
- Dassault-Aviation also has on going SAF research activities to assess our aircrafts/engines/operability and maintenance compatibility with SAF drop-in :
  - DA will wait the conclusion of these projects to ballot the specification: target end 2025

Challenges and opportunities - Conclusion

- Flow down from ASTM fuel regulations to EASA CS-25 & CS-E aircraft regulations
  - CRI release for new TC ? Certified aircrafts and engines ?
  - Level of task required for approval in the AFM to be clarified
  - Operational feedback from EASA ?

- Need to accelerate SAF availability everywhere:
  - Book-and-Claim

- Next step: Jet X?

EASA position welcome to support R&I orientations

Back-up

100% SATF DROP IN OBJECTIVES

- Contribution to 2050 decarbonation roadmap
- Principle : (extract from Research Report V1.2)
- Objectives:
  - Drop in concept : compatible to existing aircrafts
  - Homologation through D7566 then D1655 : possible to avoid major modification for introduction in AFM/EMM (if revision of these standards are alreac deleted)
- Nolveties :
  - SBC could be mixed together to create a final product

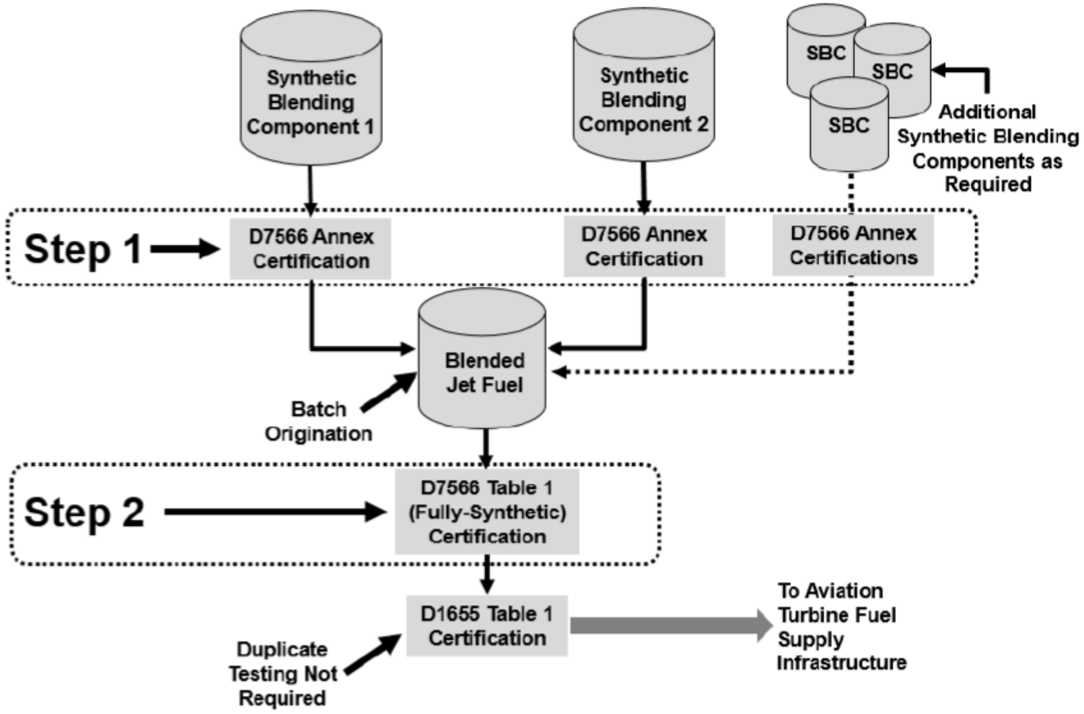


Figure 5. Proposed process for certifying fully synthetic aviation turbine fuel produced from two or more annexes

100% SATF DROP IN SPECIFICATION PROPOSAL VS CERTIFICATION REQUIREMENTS

- Auto ignition temperature :
  - Certification requirement : CS25.981
  - Linked to Catastrophic Event at aircraft level
  - Criteria : Maximum allowable surface temperature of 400°F (ie 204,4°C) considering safety margin of 50°F
- Impacts on Aircraft design :
  - Fuel equipment: hot spot/ electrical definition etc
  - Fuel system: thermal analysis/pressurized air for fuel tank temperature requirements (specific Falcon)
  - Air system: bleed air temperature requirements

CS 25.981 Fuel tank explosion prevention
(See AMC 25.981)

(a) No ignition source may be present at each point in the fuel tank or fuel tank system where catastrophic failure could occur due to ignition of fuel or vapours. This must be shown by:

(1) Determining the highest temperature allowing a safe margin below the lowest expected auto-ignition temperature of the fuel in the fuel tanks.

(2) Demonstrating that no temperature at each place inside each fuel tank where fuel ignition is possible will exceed the temperature determined under sub-paragraph (a)(1) of this paragraph. This must be verified under all probable operating, failure, and malfunction conditions of each component whose operation, failure, or malfunction could increase the temperature inside the tank.

(3) Except for the ignition sources due to lightning addressed by CS 25.954, demonstrating that an ignition source could not result from each single failure, from each single failure in combination with each latent failure condition not shown to be extremely remote, and from all combinations of failures not shown to be extremely improbable, taking into account the effects of manufacturing variability, ageing, wear, corrosion, and likely damage.

09/24/18 AC 25.981-1D
Appendix C

C.21 **LATENT FAILURE.**
A failure whose presence is not apparent to the flightcrew or maintenance personnel. A significant latent failure is one that would, in combination with one or more specific failures or events, result in a hazardous or catastrophic failure condition.

C.22 **LINE REPLACEMENT UNIT (LRU).**
Any components that can be replaced while the airplane remains in operational service. Examples of fuel system LRUs include components such as flight deck and refueling panel fuel quantity indicators, fuel quantity system processors, and fuel system management control units.

C.23 **MAXIMUM ALLOWABLE SURFACE TEMPERATURES.**
As defined in 14 CFR 25.981(a)(1) and (2), the surface temperature within the fuel tank (the tank walls, baffles, or any components) that provides a safe margin under all normal or failure conditions, which is at least 50 °F (27.8 °C) below the lowest expected autoignition temperature of the approved fuels. The autoignition temperature of fuels will vary because of a variety of factors (ambient pressure, dwell time, fuel type, etc.). The value accepted by the FAA without further substantiation for kerosene fuels, such as Jet A, under static sea level conditions, is 450 °F (232.2 °C). This results in a maximum allowable surface temperature of 400 °F (204.4 °C) for an affected component surface.

100% SATF DROP IN SPECIFICATION PROPOSAL VS CERTIFICATION REQUIREMENTS

- NEAT SBC known AIT :

NEAT SBC	AIT (°C)	NEAT SBC containaing aromatics ?
Annex 1	ASTM research report : 247	Yes
Annex 2	ASTM research report : 222 VOLCAN project : 197	No
Annex 3	No data	No
Annex 4	ASTM research report : ~247	Yes
Annex 5	No data	No
Annex 6	ASTM research report : ~230	Yes
Annex 7	No data	No
Annex 8	No data	Yes

From ASTM D 1655 to CS-25 & CS-E

1. Engine/APU operability assessment including certified operating domain for restart/relight and associated demonstration at aircraft level (CS 25.903): cetane number, density, viscosity at low temperature.

2. Fuel Tank Ignition Source Prevention (CS 25.981): sparking energy (<50 mJ), maximal allowable surface temperature (50°F below ignition temperature).

3. Fuel tank Flammability Reduction Means (CS25 Appendix M): fuel Flash Point, oxygen in fuel dilution and then release.

4. Water in fuel contamination (CS-E 470): concentration to be considered for safe engine operation including slush release.

5. Fuel gauging (CS 25.1305): fuel permittivity characteristic (K), density.

6. Fuel pumping (CS-E 660): Vapor to Liquid ratio (vapor lock, fuel pump cavitation).

7. Blend of blend: demonstration that the fuel key characteristics will remains within the certified limits in presence of variable SAF blends levels along time operation and especially to clear the risks of stratification which may occur in the fuel tank due to the larger density variability.

8. Airworthiness Limitations Section (H25.4): each mandatory replacement time, inspection interval, related inspection procedure, and all the critical design configuration control limitations approved under CS 25.981 for the fuel tank system and especially regarding seal leakage prevention without aromatics added

9. Aircraft CO2 emissions: assessment methodology of CO2 benefits as per ICAO Annex 16 Volume III to be considered.

EASA position welcome to support R&I orientations