





# Update on 100% SAF testing and recent achievements









Provide participants with updated information on the ongoing industry efforts to carry out 100% SAF testing, and updates on recent achievements related to 100% SAF flights.





#### **ACT-SAF Series #14 Speakers**



#### **Helen Kennett**

Director Government Relations Rolls-Royce plc



#### **Alastair Hobday**

Associate Fellow Fuels and Lubricants
Rolls-Royce plc



#### Lucia Garcia-Matas

Design and Development
Engineer
Virgin Atlantic Airways

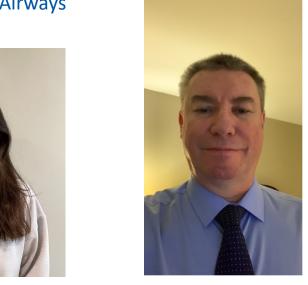


#### **Kevin Bower**

Aviation Quality Manager bp



ecoDemonstrator
Alternative Energy Lead
and Technical Advisor
The Boeing Company







#### **Agenda**



- Opening remarks by ICAO
- ICAO update on ACT-SAF activities
- Presentation by Rolls-Royce on 100% SAF compatibility testing
- Presentations by Rolls-Royce, Virgin Atlantic, air bp and Boeing on 100%
   SAF transatlantic flight (Flight100)
- Presentation by Rolls-Royce on what's next
- Questions and answers with the audience
- Closing remarks by ICAO











### Marked increase in number of ACT-SAF partner States/Organizations

- Increased opportunities for expert contributions towards training, feasibility studies, etc.
  - Close to 200 ACT-SAF Partner States and Organizations
  - Increase in partners supports further outreach of SAF development and deployment initiatives
  - Initiating discussions with new partners

ICAO Assistance, Capacity-building and Training for Sustainable Aviation Fuels (ICAO ACT-SAF)



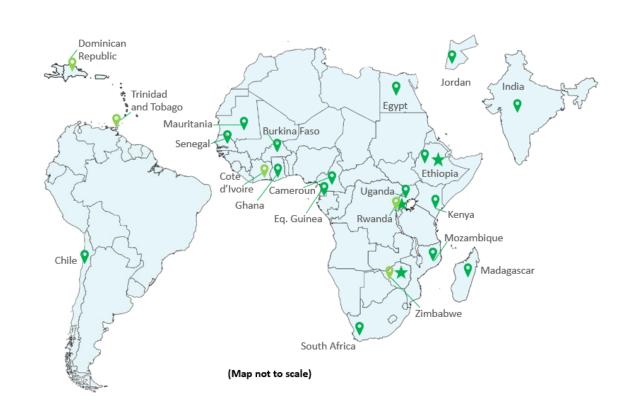






# Coordination of ACT-SAF feasibility / business implementation studies

- Contributions to the ENV Fund
  - Airbus, Austria, Côte d'Ivoire, France, Netherlands, UK, and EU
- Initial tranche of studies to begin
  - Final stages of contracting for feasibility / business implementation studies for India, Ethiopia, South Africa, and Zimbabwe
  - Others to commence thereafter
- ICAO to coordinate additional studies
  - > Target for 20 in 2025, and 50 by 2028







#### **Recent initiatives from ACT-SAF partners**

- RSB / Boeing study on sustainable feedstock potential in Southeast Asia
  - Highlights region's capability to supply around 12% of global SAF demand by 2050
  - Noted gaps in available scientific research on various feedstock/regions, further research needed

RSB launches study with Boeing on sustainable feedstock potential in Southeast Asia

September 3rd, 2024



- IATA Report Lessons for aviation on policies used to support the creation of new renewable energy markets
  - Highlights crucial role of governments, tailor made energy policy frameworks, and strategic policy sequencing
  - Case studies in solar / wind energy markets









# Policy developments from ACT-SAF partners

- Republic of Korea all international flights to use sustainable fuel from 2027
  - ➤ SAF expansion strategy announced 30 August 2024, by Ministry of Trade, Industry and Energy, Ministry of Land, Infrastructure and Transport, and other stakeholders
  - ➤ All national airlines will be required to include at least 1% SAF in their jet fuel
  - Incentives planned, easing of regulations for easier access to feedstock
  - ➤ Ties in with SK Energy commencing SAF commercial production in the Republic of Korea.



Minister of Trade, Industry and Energy Ahn Duk-geun, third from left, and Minister of Land, Infrastructure and Transport Park Sang-woo, fourth from left, pose with other dignitaries holding copies of a memorandum of understanding on using sustainable aviation fuel (SAF) to fuel the country's commercial flights to counter climate change, at Incheon International Airport, Friday. From left are Korea Airports Corp. Executive Vice President Lee Jeong-ki, Korea Petroleum Association Chairman Park Joo-sun, Ahn, Park, Incheon International Airport Corp. President & CEO Lee Hag-jae and Korea Civil Aviation Association Vice Chairman Park Jong-heum. Korea Times photo by Shim Hyun-chul





# **ICAO** Regional Seminars on Environment (Ongoing)

- Five in-person events held from 7 August 16 October 2024
- Four sessions have concluded, final session for Eastern and Southern African (ESAF);
   Western and Central African (WACAF) regions, in Dakar Senegal, from 15-16 October
   2024
- Objectives to raise awareness and exchange views on aviation cleaner energy policies, State Action Plans, CORSIA, implementation challenges, ACT-SAF, financing, as well as means for monitoring the progress for the implementation of the LTAG and Global Framework







# ICAO Symposium on Non-CO<sub>2</sub> Aviation Emissions

- Highlighting the importance of enhanced cooperation on aviation non-CO<sub>2</sub> emissions
  - Landmark symposium held from 16-18September 2024
  - Focus on topics such as contrail formation, nitrogen oxides, and particulate matter
  - Strived to understand and enhance the climate science, potential mitigation measures and policy options
  - Access the recording of the event <u>here</u>







# Upcoming: ICAO LTAG Stocktaking Event on Aviation CO<sub>2</sub> Emissions Reduction

#### Registration is still open

Response to the 41st Session of the ICAO Assembly's request to monitor the progress towards the achievement of the collective LTAG, and the ICAO Global Framework on SAF, Lower Carbon Aviation Fuels (LCAF) and other aviation cleaner energies.

#### ACT-SAF Connect – side event on 11 October 2024

- Opportunity for ACT-SAF partners to gather in-person to discuss and further progress the programme
- Three roundtable discussions focusing on training, feasibility studies, and post feasibility-studies towards SAF production projects











#### 100% SAF compatibility testing





Our commitment to net zero and the decarbonisation of aviation



- Rolls-Royce is committed to net zero by 2050
- We are committed to the decarbonisation of aviation
  - Our company initiatives
  - Supporting ICAO
- 3 factors in the scaling of SAF
  - Demand signal Governments and airlines
  - Technically possible will it work on current engines
     / aircraft
  - Finance how we scale production



#### 100% SAF compatibility testing





The challenge we set ourselves: 100% SAF compatibility testing at Rolls-Royce

• In 2021 we set ourselves the challenge of all our in production engines across our Trent wide body and business aviation to be 100% compatible with 100% SAF by the end of 2023 to demonstrate there are no engine technology barriers to the use of 100% SAF.

• Compatibility testing as the technical pre-requisite to enable

the transatlantic flight (Flight10@









# 100% SAF compatibility testing





Our journey to Net Zero carbon is all about efficiency

Super-efficient gas turbines will power the majority of aircraft out to 2050.

Our approach is to maximise the efficiencies of current and future fleet and ensure they are compatible with 100% SAF.

In parallel, we research and develop options for future aircraft.

Maximise efficiency Ensure fleets are Develop alternatives such as electric and hydrogen of current and compatible with future fleets 100% SAF Greener fuel Zero-carbon energy Less fuel

Aircraft installation and integration

In-service support

Manufacturing and Operations



#### **ENVIRONMENT**

# 100% SAF compatibility testing





There is no technology barrier to the use of 100% SAF.

#### Rolls-Royce 100% SAF ground testing completed

		A section of the sect				
	Trent 1000 (ALECSys lean burn demo)	Trent 800 on B777 eco-demonstrator	UltraFan technology demonstrator	Trent 1000 (transatlantic challenge)	Trent XWB-97	Trent 7000
SAF tested & partners	World Energy HEFA Shell, SkyNRG	Air bp HEFA Boeing	Air bp HEFA	Air bp HEFA & Virent SAK Virgin Atlantic, UK Gov	100% Air BP HEFA	100% Air BP HEFA
Location & Dates	Derby UK December 2020	Seattle, Washington, USA October 2022	Derby, UK May 2023	Derby, UK July 2023	Derby, UK Sept 2023	Derby, UK Oct 2023
Key Tests	Starting, operability, performance and emissions					
Key Findings	All engine tests were successfully completed and all priority test points achieved  None of the engines encountered any problems running with these variants of SAF component  Engine behaviour across all tests was equivalent or better when compared to running with regular Jet A-1 fuel  Nothing was identified in these short tests that would prove detrimental for incorporation of these variants of SAF in an existing or future Rolls-Royce engine  Valuable lessons were learned in terms of tanks/refuelling systems for 100% SAF use going forward					



#### ENVIRONMENT

#### 100% SAF compatibility testing





There is no technology barrier to the use of 100% SAF.

#### Rolls-Royce 100% SAF flight testing completed

		A380	POWERING ON THE PROPERTY OF TH		Committee of the Commit
	Trent XWB-84 on A350 FTB (ECLIF3)	Trent 900 on A380 FTB	Trent 1000 on R-R 747 FTB	Trent 700 on MRTT Voyager	BR725 on G650
SAF tested & partners	Neste HEFA Airbus, DLR	TotalEnergies HEFA Airbus, PW (APU)	World Energy HEFA Boeing	Air bp HEFA Airbus, RAF, DE&S, Air Tanker	Air bp HEFA & Virent SAK Gulfstream
Location & Dates	Toulouse, France Throughout 2021	Toulouse-Nice, France March 2022	Tucson, Arizona, USA October 2021	Brize Norton, Oxfordshire, UK November 2022	Savannah, Georgia, USA December 2022
Key Tests	Understanding impact of SAF on emissions and contrails	All flight phases (take-off, climb, cruise and landing)	Altitude relight, combustor stability and engine handling	First aircraft to take off on dual-engine 100% SAF in UK	Set altitude and speed records for a biz jet on 100% SAF
	Reduced emissions due to low aromatic content of SAF Clear reduction in contrail ice particle number	Engine performed as expected throughout the 2-week test campaign 2 of the 4 engines exposed to SAF operation	Good alignment with ALECSys ground test results	Clear demonstration of SAF capability on modern Defence platform	1st Rolls-Royce 100% drop-in SAF demonstration
Key Findings	(ey Findings  All engine tests were successfully completed and all priority test points achieved				

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Valuable lessons were learned in terms of tanks/refuelling systems for 100% SAF use going forward



#### **Introducing Flight100**



Introducing our partners and Virgin Atlantic Flight100

#### **Fuel partners**





- In 2022, the UK Government launched a competition associated with delivering a transatlantic flight using 100% SAF.
- £1M of government funding was allocated to support the project.
- As a result of the competition,
   Virgin Atlantic was selected to
   deliver the flight using a Rolls Royce Trent 1000 powered Boeing
   787-9.
- The following organisations were brought together to deliver this ground-breaking project:











Imperial College London















Flight100 Regulatory Approach

- The certification documentation for the selected airframe, engine and APU does not currently include 100% drop-in SAF as an approved fuel.
  - This qualification is being actively pursued within the ASTM D02 technical committee.
- Hence the flight would be undertaken on an experimental basis, supported by a 'Permit to Fly', issued by the CAA.
- The desire was always, if possible, to be able to have individuals on board the flight.
- However, the 'Permit to Fly' process typically only allows for minimal crew to be on board.
- A rigorous and robust package of work was therefore defined and delivered, the ultimate intention being to demonstrate Jet A/A-1 equivalency for the SAF blend.

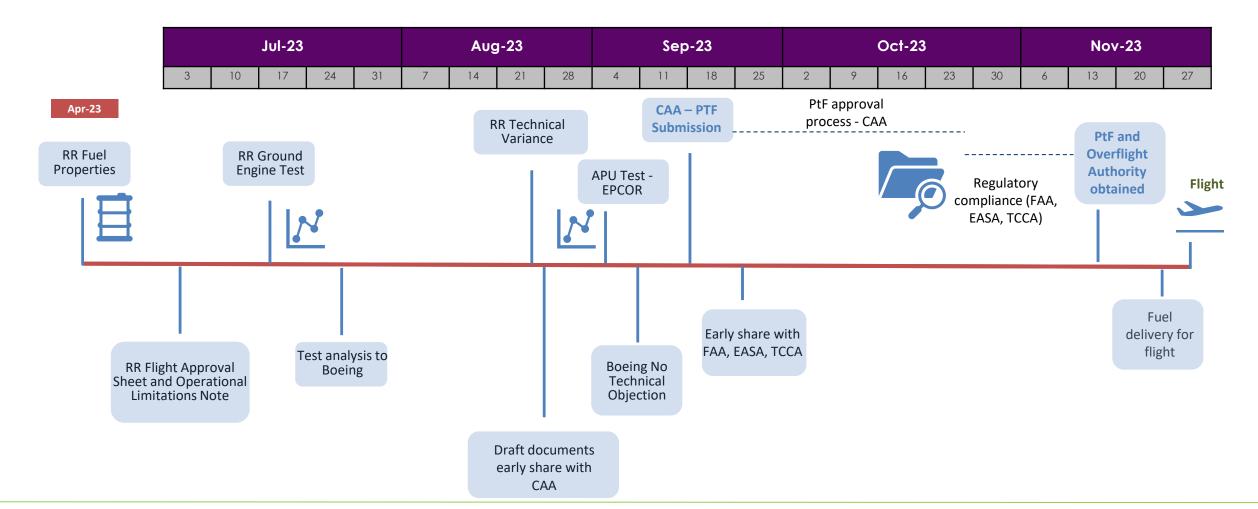




#### Programme Overview – Key steps



12 months in the making with many technical milestones required to support the submission to the regulators



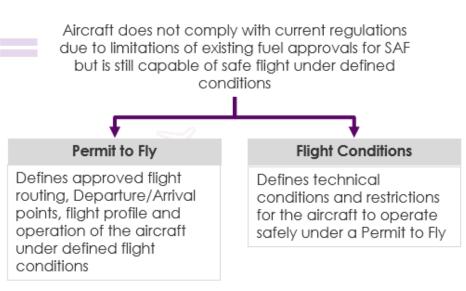


#### Approval Framework



Flight 100 operated outside of existing commercial flight framework – requiring one off Permit to Fly

		Commercial Flight	Flight 100		
	Fuel	Jet A/Jet A-1 Contains up to 50% SAF is qualified currently for use in commercial aviation	<b>100% SAF</b> Make up : 88% HEFA / 12% SAK	Aircraft does not due to limitations but is still capal	
	Certification	Type Certificate & Certificate of Airworthiness	Does not meet Type certification due to proposed fuel	Permit to Fly	
	Flight Routing	ETOPS approved Approved to 180 Minutes diversion	ETOPS NOT Approved Intent to fly per ETOPS optimal routing	Defines approved flight routing, Departure/Arriv points, flight profile and operation of the aircraft under defined flight	
On Board Observers		Not Applicable Commercial Flight approved for certified passenger capacity	Up to 110 essential observers critical to demonstrating capability	conditions	

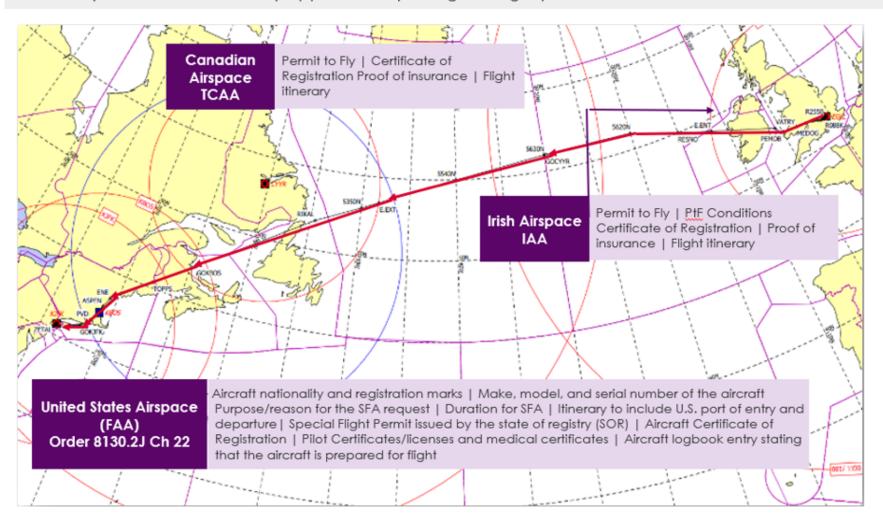


Flight100 objective: use of 100% SAF today with equivalent level of safety and airworthiness to a commercial flight on 100% Jet - A



#### Overflight Approvals

Three key civil aviation authority approvals required given flight path - Irish, Canadian and US















Fuel selection strategy

- Unlike many other recent flight demos, the intention from the outset was to only have 100% SAF on board the aircraft.
- For this to be viable meant careful fuel and fuel property selection.
- A 100% SAF drop-in solution was therefore considered the lowest risk approach.
- Hence the use of a blend of two SAF components:

HEFA-SPK from Air BP (paraffinic, qualified blend component)
HDO-SAK from Virent (aromatic, qualification in process in ASTM D02 committee)

- Rolls-Royce had previous engine/flight test experience with both above components.
- These were carefully blended in a ratio of approx. 88/12 to produce a 100% SAF that was a technical 'clone' of Jet A/A-1.







Extended fuel property database

- Laboratory blends of AirBP HEFA-SPK and Virent HDO-SAK were generated in the specified ratio.
- An ASTM D1655-type fuel specification property dataset was developed associated with the blends.
- In order to provide further evidence of technical equivalence, a more exhaustive suite of property testing was agreed between Rolls-Royce and Boeing.
- This addressed so called 'fit for purpose' properties, which are not necessarily called out in the ASTM fuel specification, such as:
  - 2-dimensional Gas Chromatography
  - Air release characteristics
  - Viscosity/density vs temp
  - Bulk modulus
  - Surface tension
  - Vapour pressure
  - Derived Cetane Number







Fuel property summary

HEFA-Virent blend properties meet D1655 / JetA-1 requirements.

Property	Test Method	Units	ASTM D7566 Annex A2	ASTM D1655 (Jet A-1)	Air BP HEFA- SPK & Virent SAK (~12% blend) Flight100
Density at 15°C	ASTM D4052	kg/m3	730-772	775-840	777.7
Aromatics	ASTM D1319	% (v/v)		Max 25	13.1
Distillation	ASTM D86	°C			
IBP					148.9
T10			205 max		173.1
T50	report		oort	224.3	
T90			report		259.1
FBP			300 max		264
T90-T10			22 min HEFA / 40 min Jet A-1 15 min Jet A-1		86
T50-T10					51.2
Kinematic Viscosity at -20°C	ASTM D445	cSt	< 8cSt	< 8cSt	5.063
Kinematic Viscosity at -40°C	ASTM D445	cSt	Not required for a neat HEFA-SPK	<12cSt for a blended fuel (<50%)	11.672
BOCLE (lubricity)	ASTM D5001	mm	max 0.85	max 0.85	0.67





# Engine ground test on Trent 1000 experimental engine

The test was conducted as a back-to-back (JetA-1 vs. HEFA-Virent blend) to confirm equivalence of engine behaviour between the two fuel types.

A total of approx. 4 hours running was completed on the SAF blend.

All target test points were achieved on both fuel types.













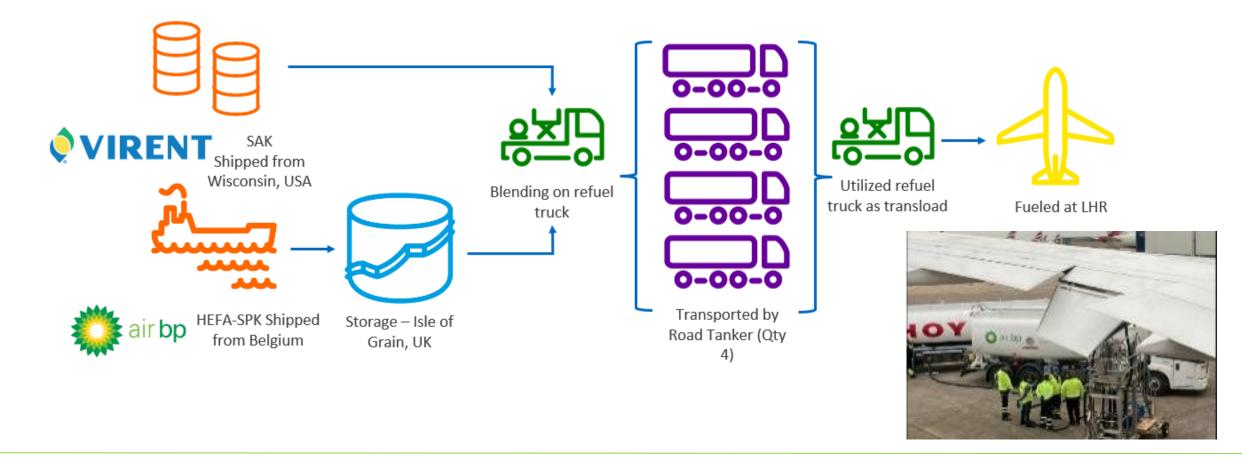


# Flight100 Blending



- A rigorous fuel handling and quality management plan was followed.
- Quality checks were conducted at each stage of the process to verify consistent fuel properties and ensure no contamination.

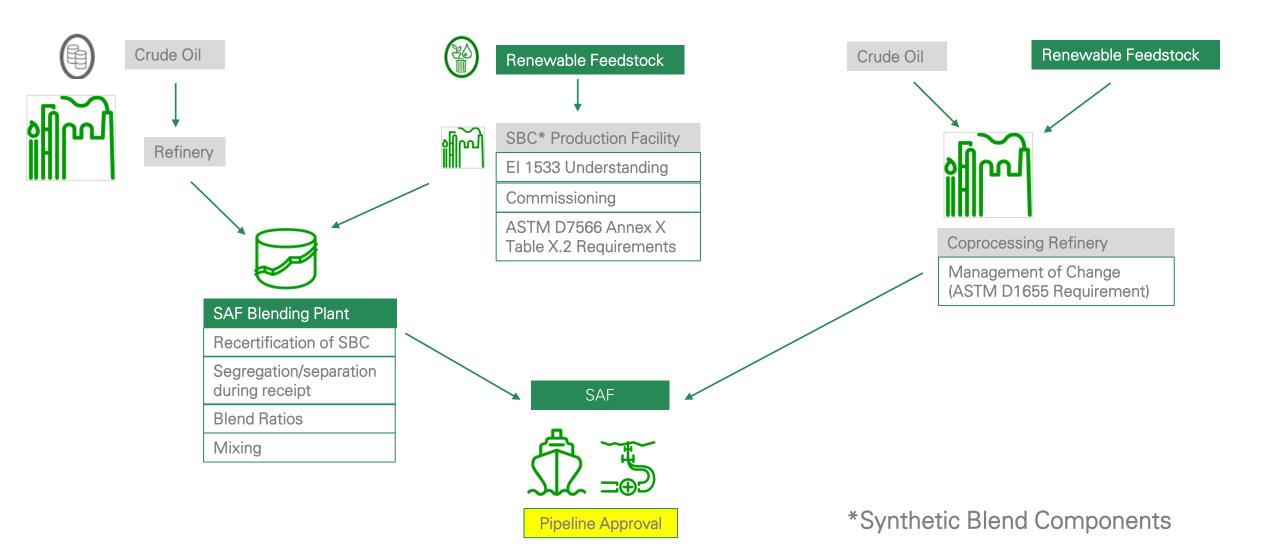






#### **Challenges for SAF Blending**













# Flight clearance progression aircraft and APU



# Fuel Properties Assessment

Airplane Level

#### Ground Test

Rolls-Royce Engine

#### Ground Test

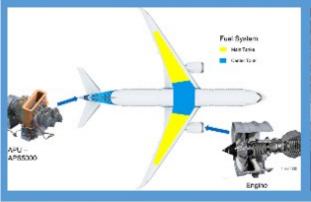
Pratt & Whitney Canada
APU

#### Airplane Ground Check

High Power Engine Run + APU Run

#### Clearance for Dual Engine Flight

100% SAF All Fuel Tanks









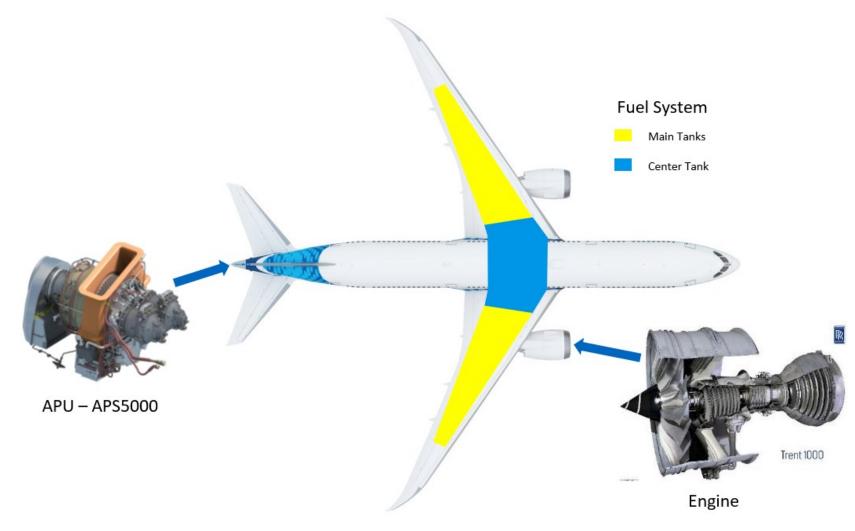






# Airplane schematic



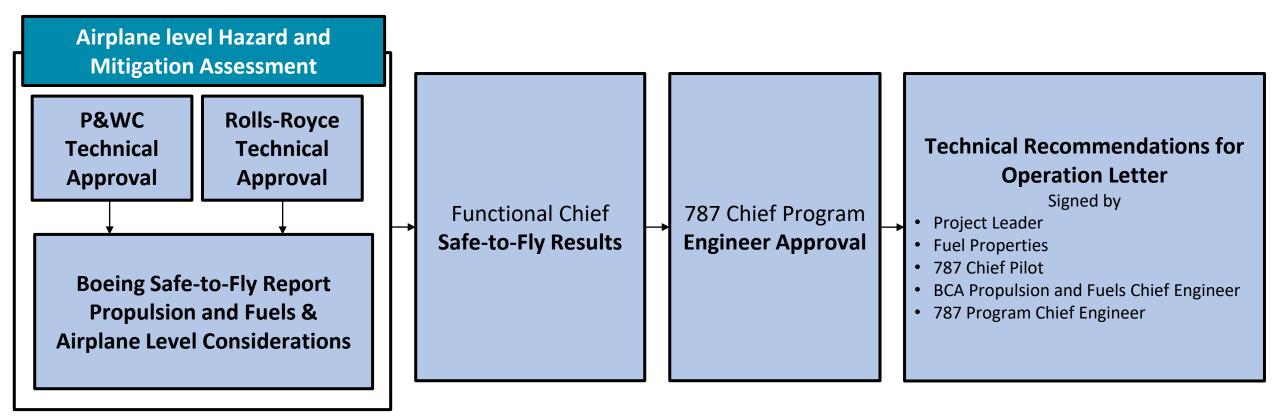






# Technical recommendations for operation





Delivery of the Technical Recommendations for Operation Letter enables Virgin Atlantic to proceed with the CAA Permit to Fly (PtF) application

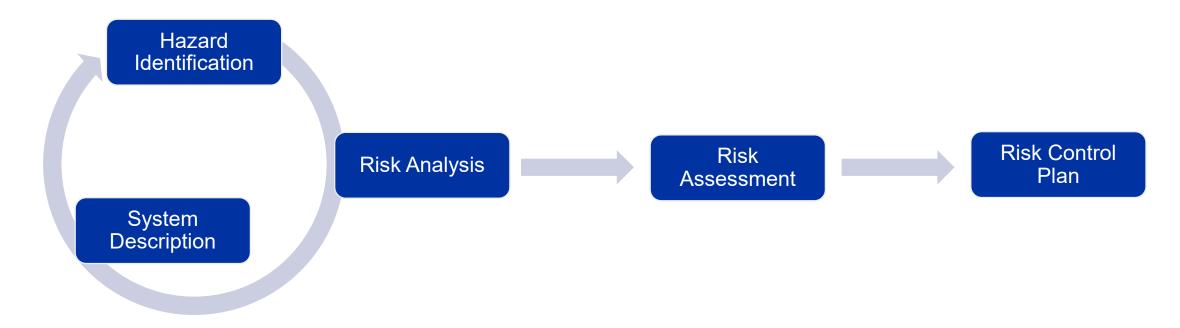




# Hazard and mitigation assessment



• As part of the Safe-to-Fly approval process Boeing conducted thorough reviews with the affected internal functional organizations, Rolls-Royce, and Pratt and Whitney Canada to identify hazards and mitigation plans needed to conduct the 100% SAF Flight safely.



The assessment resulted in technical recommendations for the 100% SAF flight that are above the requirements for standard revenue operations. However, no airplane modifications, limitations, or advisories were required for the 100% SAF flight.





## APU ground test



- Performed at EPCOR European Pneumatic Components Overhaul and Repair, an MRO facility located in the Netherlands
- Back-to-back testing Jet A and 100% SAF
  - Steady State Performance
  - Operability
  - Oil Consumption
  - Fuel System Soak
  - Teardown Inspection







# Technical data substantiation summary



#### **Fuel Properties**

CoA for representative HEFA-SPK

CoA for representative SAK

CoA for representative bench blend 88%SPK/12%SAK

Bench blend - fit for purpose properties analysis

CoA for fuel used for engine and APU ground tests

Dielectric vs Density Data from Ground Test Fuel

Fuel Handling and Quality Management Plan

CoA for Flight Fuel

#### Engine

Fluid Approval Statement (FAS)

Operational Limitation Note (OLN)

Technical Variance (TV)

Reliability Assessment – Non SAF related items

Technical Memo
Introductory info.
FAS Summary
Operability Review
Fuel Icing Assessment
Ground Test Performance
Review

#### APU

Technical Memo

Recommendations for Operation

SAF Ground Test Plan at EPCOR

SAF Ground Test Report

Special Instructions for APS5000A APU that has run with 100% SAF

#### Fuel System

Collins FQIS Impact Assessment of 787 Flight Test with 100% SAF

### Flight100



#### Return into service

- Given that the flight was undertaken on an experimental basis, action was required to return the aircraft to a revenue service condition. Rolls-Royce issued a Technical Variance to instruct engine relevant actions.
- Post-arrival into JFK, the aircraft was defueled as much as practicable.
- Engine and APU inspections were carried out to confirm acceptable condition.
- Aircraft was refuelled with fuel meeting D1655 Jet A requirements.
- Engines and APU were operated for a specified period to purge lines of any residual SAF fuel blend.
- Aircraft returned to service as per normal procedures.

The aircraft returned to LHR the following day on a revenue flight, with no issues reported.



#### Technical Variance



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Rolls-Royce pla Proprietary Information - Not for Manufacture



## Flight100











Conclusions / lessons learnt

- Delivery of a project with such complexity is challenging and requires significant commitment and resources.
- With the right level of technical rigour and diligence, extraordinary things can be done.
- A typical permit to fly would only permit skeleton crew we were ultimately granted approval to have 100 observers on board.
- Fuel supply immaturity means those logistics need careful consideration assessment.
- Shipping, blending, testing, quality assessment, delivery to aircraft, defueling etc..
- Aircraft flew back the following day on Jet A fuel, proving the agnostic capability.
- Potential for long distance flight on 100% SAF has now been realised.

















'Sustainable flight is too difficult' Challenge accepted

100% SUSTAINABLE AVIATION FUEL

FLIGHT 100

28.11.23

virgin atlantic









#### What's next?





Our commitment to net zero and the decarbonisation of aviation



- SAF remains an industry effort, there is a strong technical community in place to enhance SAF technologies.
- Beyond this, Rolls-Royce has had a long-standing commitment with ICAO and will continue to support:
  - @ICAO LTAG stocktaking in 7<sup>th</sup> 10<sup>th</sup> Oct 2024
  - @ICAO LTAG stocktaking ACT-SAF side event 11<sup>th</sup> Oct 2024















## **Upcoming ICAO Events**





#### **ICAO LTAG Stocktaking event**

7-10 October 2024, ICAO HQ, Montreal, Canada

https://www.icao.int/Meetings/LTAGStocktaking2024/



## Follow up actions



#### We need your assistance on the following actions:

- Provide inputs/ideas for upcoming ACT-SAF training series
- Suggest possible consultants with suitable expertise for the upcoming ACT-SAF Projects.
- Contact ICAO if your State is looking for any specific support (e.g. local training)
- Provide inputs to ICAO SAF tracker tools

Responses to officeenv@icao.int will be appreciated

