

Flight 100 Boeing Report Out

June 2024

Manufactured by
FLIGHTLINE
SUPPORT LTD
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www.flightline.co.uk
8000 200 Page
Training Manual 20 000
EPA Protected Air part
and weight 500 kg

DO NOT WORK UNDER PLATFORM
UNLESS PLATFORM IS SECURELY PROPPED

G-VDIA

A Legacy of SAF Demonstrations

2008
First SAF test flight



5%



100%

2023
First 100% SAF
transatlantic flight on a
commercial aircraft



2008

2010

2012

2014

2016

2018

2020

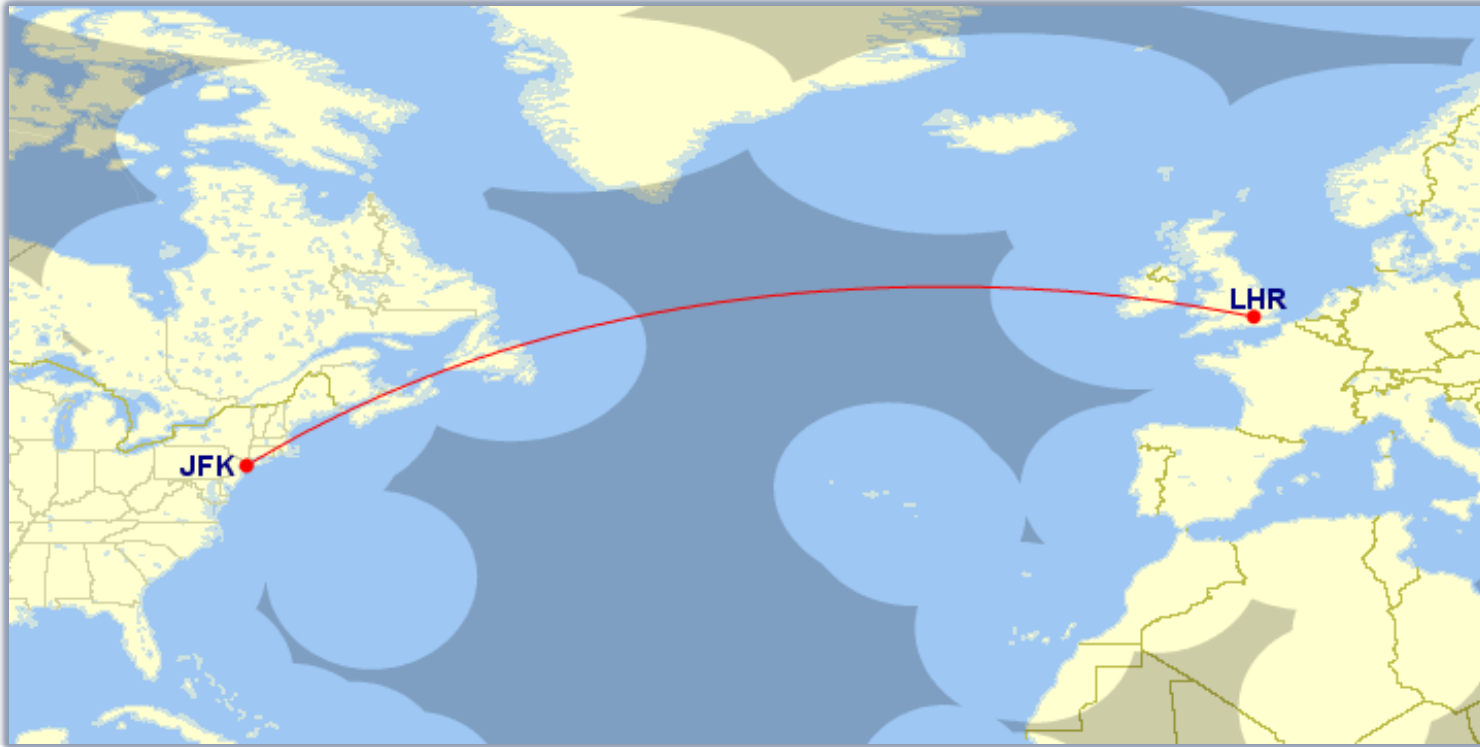
2022

2024

Virgin Atlantic 100% SAF Flight

28 November 2023

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- From LHR to JFK
- Operated under CAA Permit to Fly
- World's busiest route by available passenger seat kilometers

Demonstrated the operational viability of using 100% SAF on a flight in both engines of a passenger-carrying Boeing 787-9 across the Atlantic

Consortium Members

Solicitation from UK Department for Transport managed by Innovate UK

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Imperial College
London



University of
Sheffield



Decarbonizing Aerospace

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Flight 100 is a blueprint for cross-sector partnerships

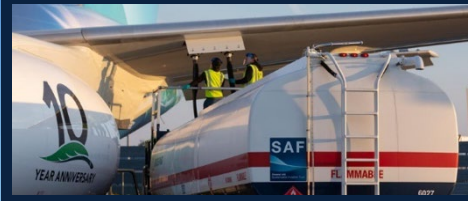
FLEET RENEWAL



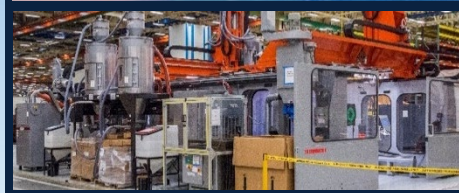
OPERATIONAL EFFICIENCY



RENEWABLE ENERGY



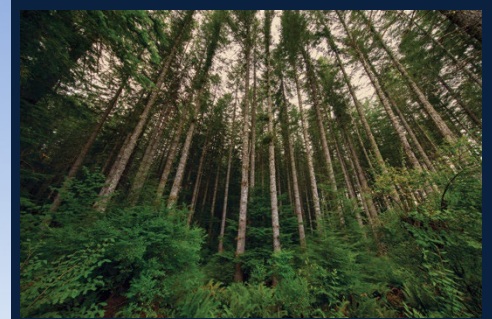
ADVANCED TECHNOLOGY



MARKET-BASED MEASURES



CORSIA



100% SAF Compatibility

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Boeing has committed that by 2030 its commercial airplanes will be 100% SAF compatible



**Developing
Jet Reference Fluids**



**Testing
Materials & Systems**



**Mobilizing
Partners**



**Engaging
Across Industries**

The learnings from Flight 100 are helping pave the way for that to become a reality

Boeing SAF Milestones

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Technology & Testing

2008
First SAF test flight with Virgin Atlantic



2010
U.S. Navy F/A-18 supersonic flight on 50/50 SAF blend



2011
HEFA pathway research approved

2018
First commercial airplane test on 100% SAF



2021
Committed to 100% SAF compatible airplanes by 2030

100% SAF flight with Rolls-Royce

First 100% SAF passenger flight with United Airlines, one engine

2021-2023
SAF emissions testing with NASA



2023
Developed jet reference fluid to test 100% SAF compatibility

2023
First 100% SAF transatlantic commercial flight with Virgin Atlantic, dual engine

2024
IAEG 100% SAF Compatibility Working Group



Operations



2012-ongoing
Use biofuel on every Boeing ecoDemonstrator program

2018
Launched program for biofuel delivery flights from Boeing Delivery Centers

2022
7.5M liters of SAF procured for operations

2023
21.2M liters of SAF contracted for operations

2024
35.6M liters of SAF bought for operations

Partnerships & Policy

2009
Sustainable Aviation Fuel Users Group (SAFUG)

2011
First regional multi-stakeholder roadmaps in the US, Australia

2014
ASTM approval of Green Diesel pathway with Neste

2021
Partnered with SkyNRG



2022-ongoing
Region-specific roadmaps and SAF feedstock analyses with local partners



2023
Studied SAF's impact on contrails with NASA, United, DLR



2023
Spearheaded Air-CRAFT, a UAE SAF consortium

Launched APEC SAF initiative with U.S. Government

Collaborated with Masdar and Zero Petroleum

2024
Partnered with Wagner Sustainable Aviation Fuels

Journey Towards Net Zero

Boeing supported and consulted on several Flight 100 work streams

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- SAF Testing and Approvals



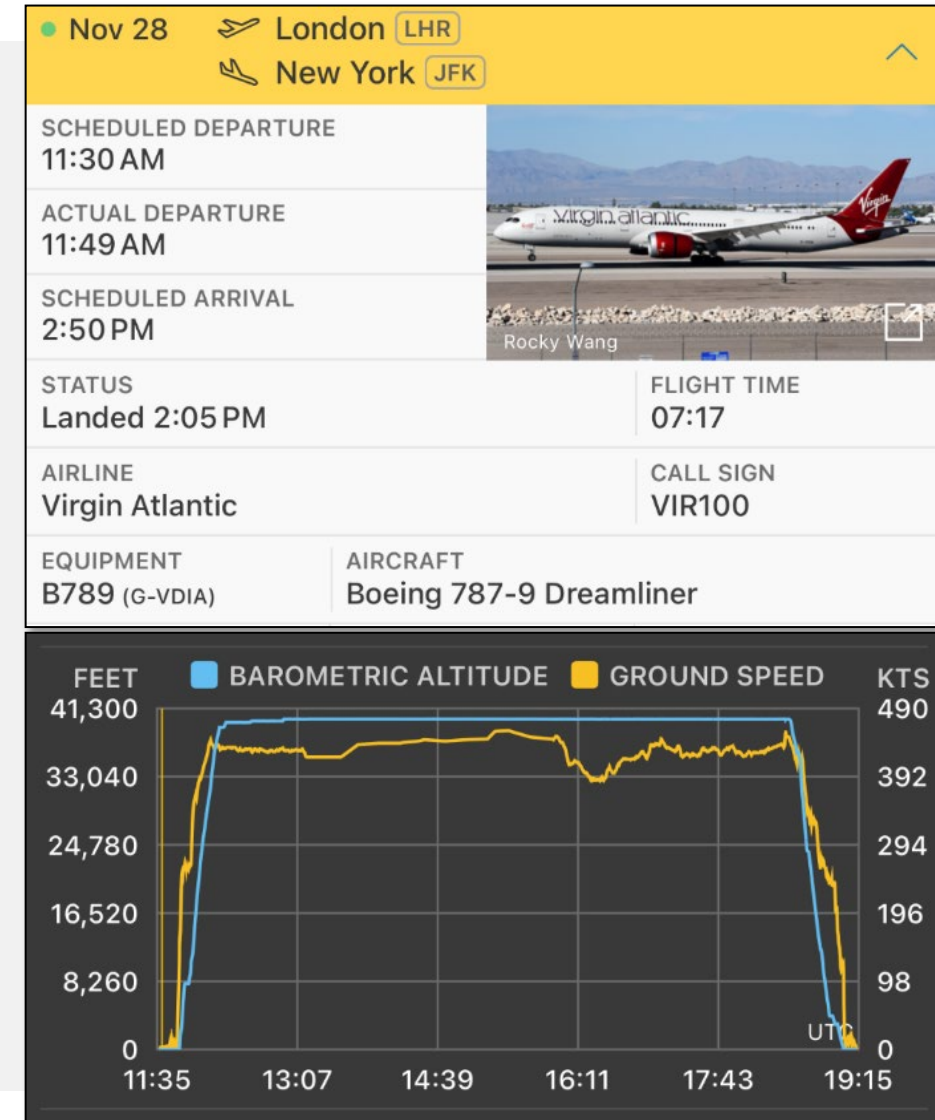
- Flight Optimization



- Lifecycle Analysis & Carbon Removals



- Non-CO₂ Effects

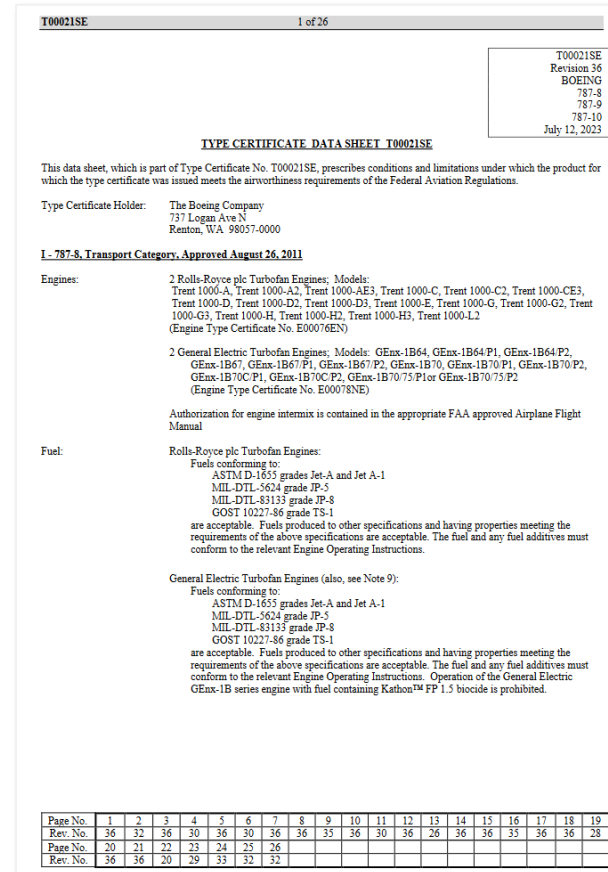


787-9 Approved Fuels

Airplane Flight Manual (AFM)



Type Certificate Data Sheets (TCDS)



Approved fuels are listed in airplane and engine documents pertaining to operation and airworthiness

Synthetic Fuel Classification



Designation: D1655 – 21a

**Standard Specification for
Aviation Turbine Fuels¹**



Designation: D7566 – 21

**Standard Specification for
Aviation Turbine Fuel Containing Synthesized
Hydrocarbons¹**

Synthetic fuel that meets Table 1 of D7566, meets the requirements of Specification D1655 and shall be regarded as Specification D1655 turbine fuel.

However, when considering the 100% SAF for Flight 100,

- The blending component limit for Annex A2 (HEFA-SPK) of D7566 is 50%
- Synthetic Aromatic Kerosene (SAK) is not currently an approved blending component

As a result, Flight 100 was completed as experimental category under UK CAA Permit to Fly.

Flight Clearance Progression

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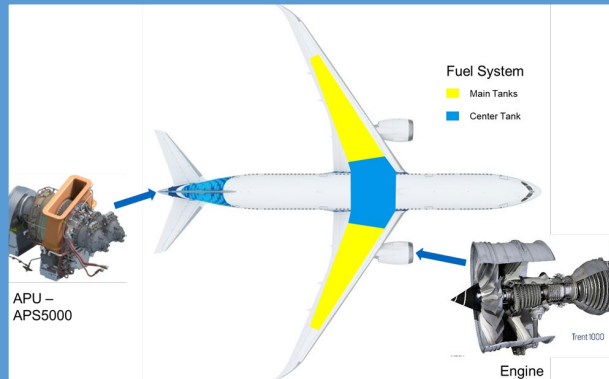
Fuel Properties Assessment
Airplane Level

Ground Test
Rolls-Royce Engine

Ground Test
Pratt & Whitney Canada APU

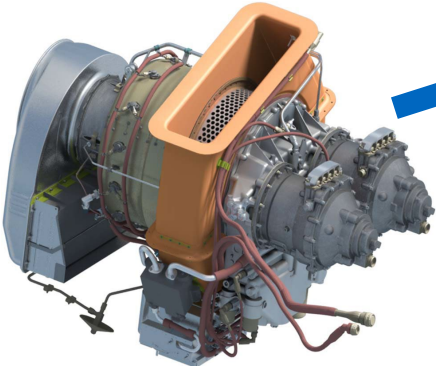
Airplane Ground Check
High Power Engine Run + APU Run

Clearance for Dual Engine Flight
100% SAF All Fuel Tanks

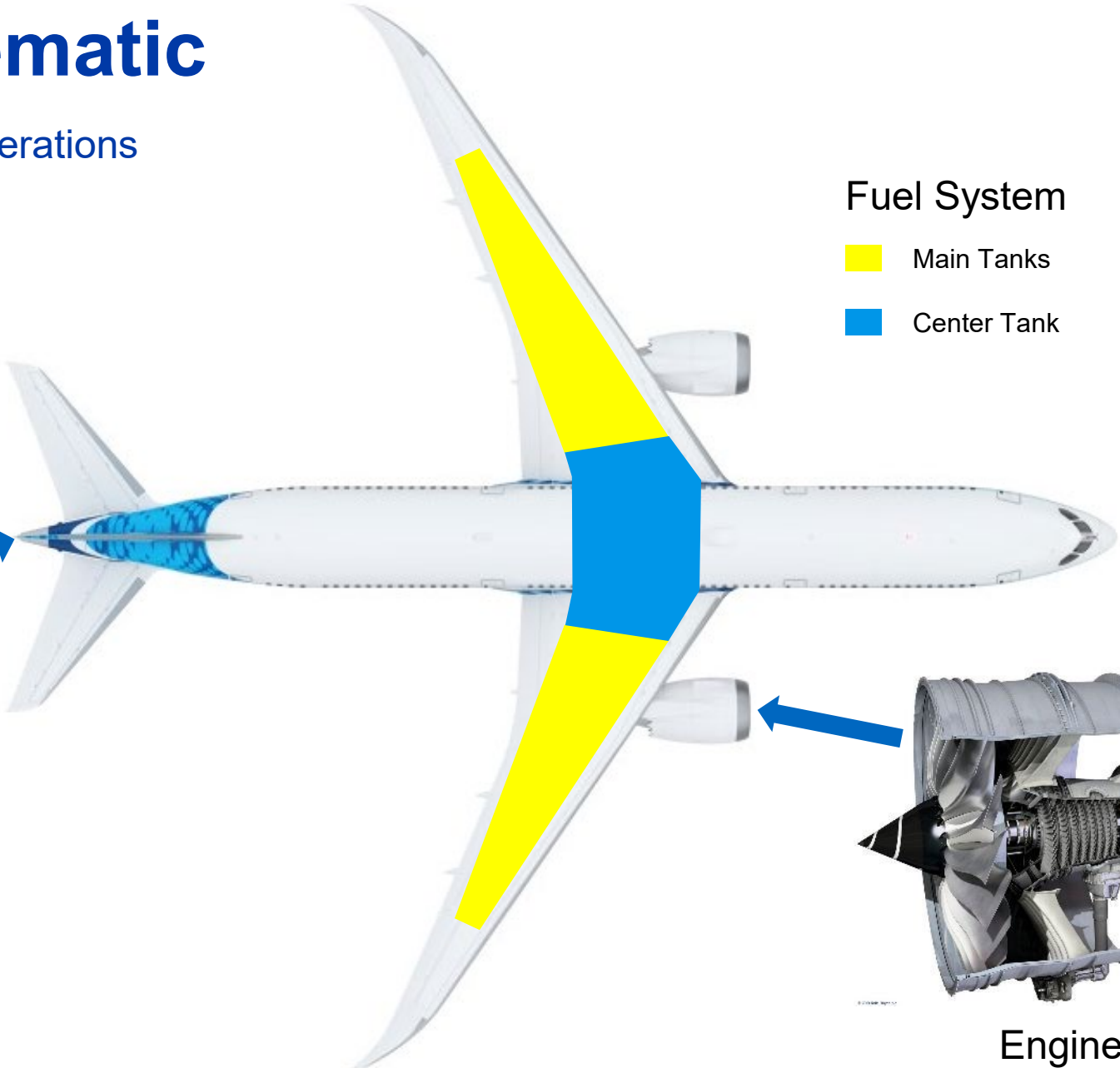


Airplane Schematic

Primary areas for fuel considerations

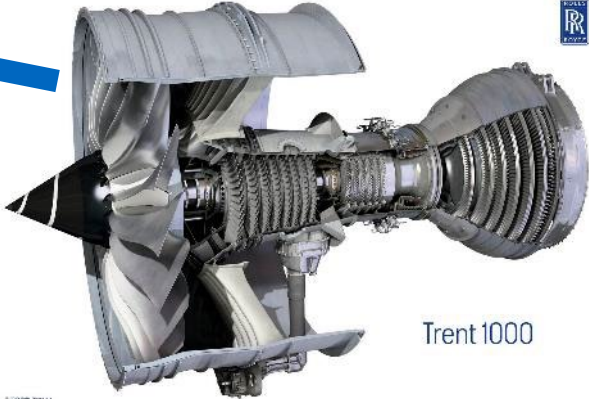


APU –
APS5000



Fuel System

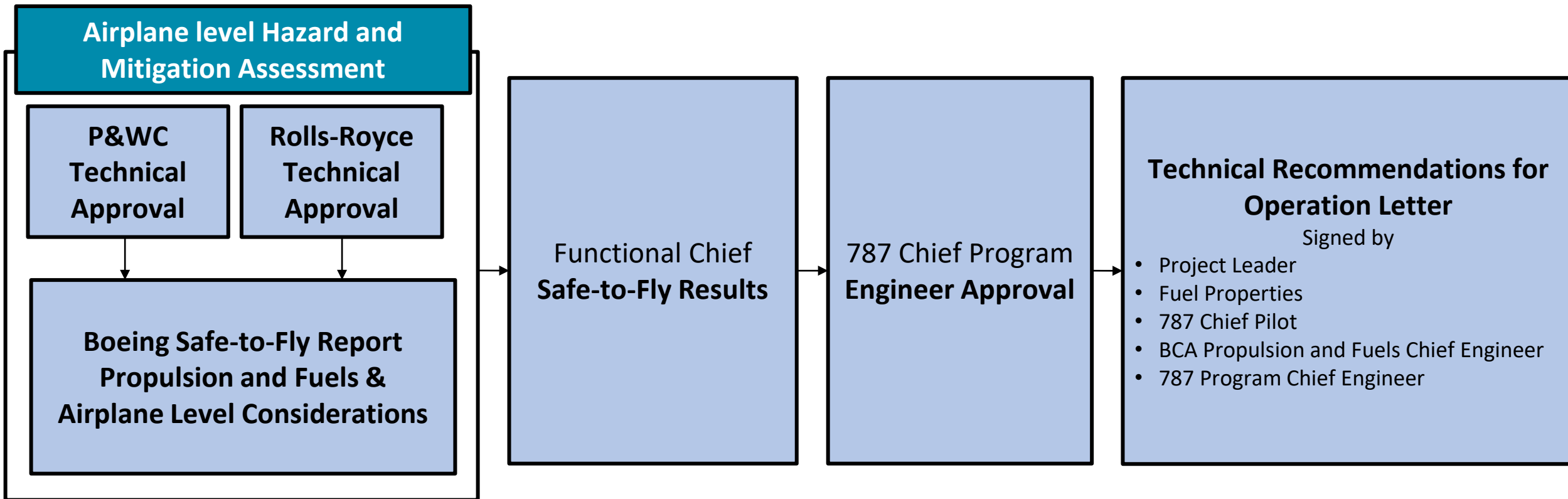
- Main Tanks
- Center Tank



Trent 1000

Engine

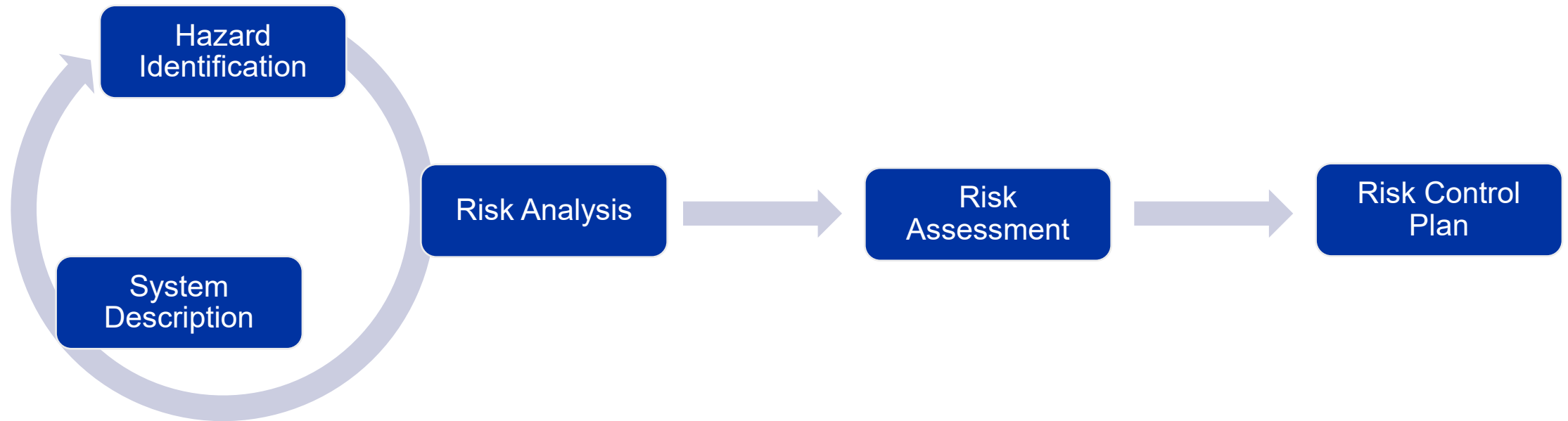
Technical Recommendations for Operation



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 results of 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 located in the Netherlands

Back-to-back testing Jet A and 100% SAF

- Steady State Performance
- Operability
- Oil Consumption
- Fuel System Soak
- Teardown Inspection

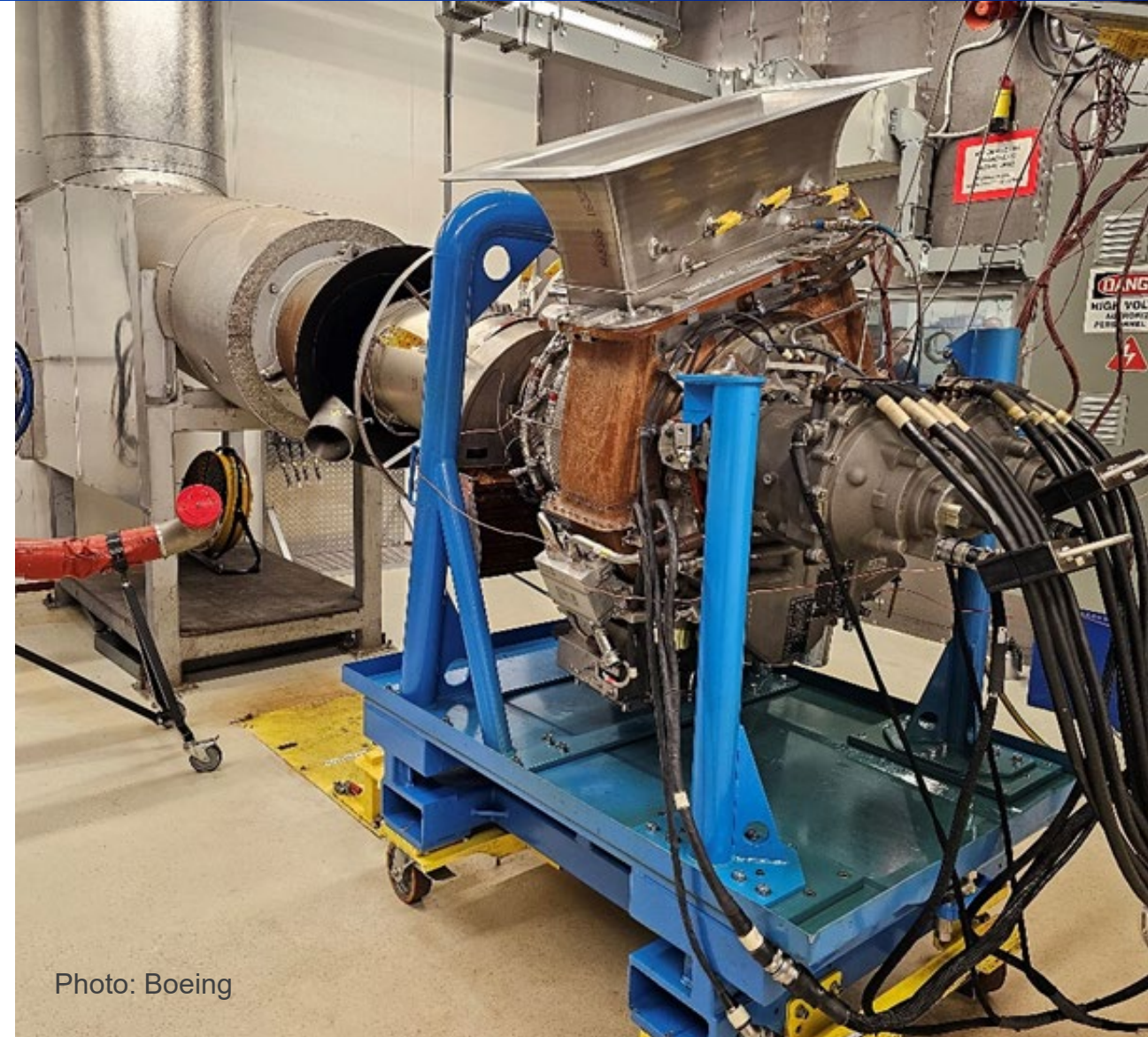


Photo: Boeing

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

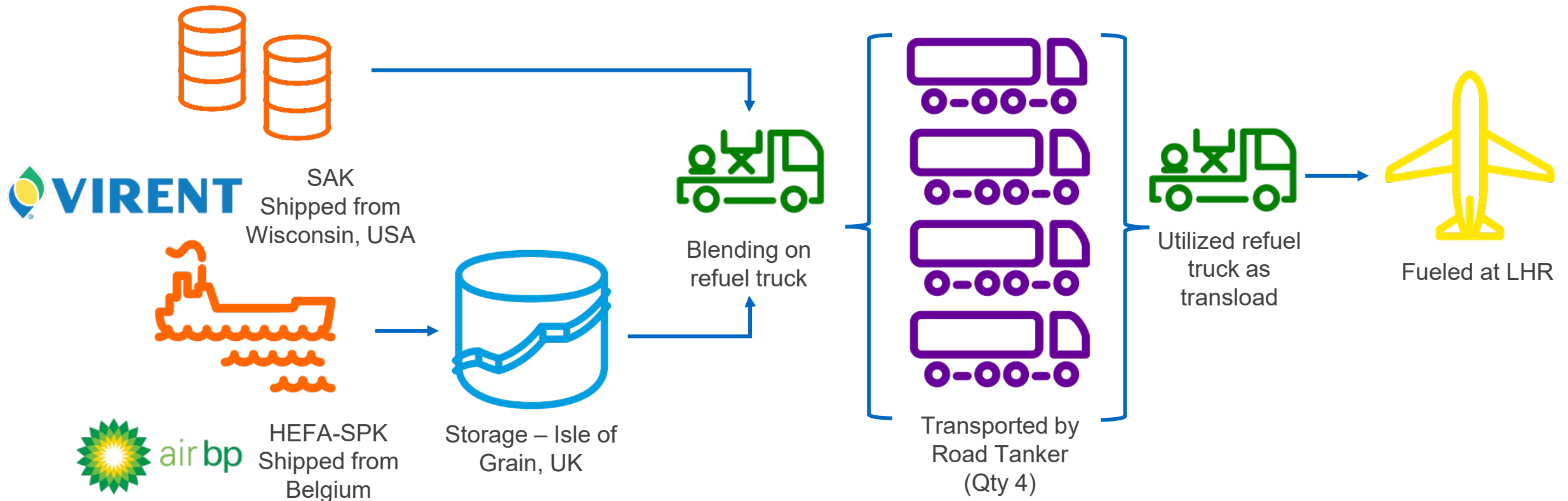
Fuel System

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

Fuel Blending and Handling

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.



Observations – Airplane Operation

CPL and EAFR data assessment

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Fuel System

- Fuel Quantities
- Fuel Pump Commands
- Fuel Density
- Fuel Temperature
- Fuel Totalizer
- Fuel Calculated Estimate
- Body Lat, Norm, and Long Acceleration (g)

Engine

- Rolls-Royce conducted a detailed engine performance analysis after each segment

APU Parameters

- EGT
- Fuel Flow
- Shaft Speed
- Oil Pressure
- Fire Switch
- Fuel Pump Command
- Ignition Exciter
- Oil Qty
- Oil Temp

AHM Data

- Summary of all fault reports (e.g. ATA 28, 49, 73)
- No anomalous observations

CPL (Continuous Parameter Logging) / EAFR Enhanced Airborne Flight Recorder Data

- A 100% SAF flight on a transport category airplane, in simulated commercial operations, is technically achievable
- The flight clearance progression resulted in a 100% SAF flight with no Flight Deck Effects or anomalous fuel system, engine and APU behavior
- Government support, through policy, mandates, incentives, or funding (e.g. 100% SAF Flight Fund) is critical to bring companies, especially internationally, together to tackle the energy transition
- The adoption and implementation of SAF is still in early stages. Projects like Flight 100 are vital to bring everyone in the commercial airplane value stream to a common level of knowledge/understanding
- It is important, especially near term, to continue development of fully formulated SAF blends that may be approved for 100% usage
- Airplane manufacturers, engine companies, APU suppliers, and component suppliers have unique requirements imbedded in their designs and product capabilities that rely on "fit for purpose" fuel properties. That information needs to be documented and shared with fuel specification committees.
- It is important to capture learnings and share best practices to help the industry at large progress more quickly on the SAF adoption journey

By the Numbers – Boeing

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>75

Total Boeing
personnel

6

Boeing sites

DOZENS

of parameters
monitored real-time
during Flight 100



