

Pratt & Whitney:
A Multi-fuel Propulsion System Strategy For Aviation Transport Resilience

Pratt & Whitney
An RTX Business

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New Energy Carriers

Reasons to pursue alternative fuels

- Energy security
- Emissions reduction (CO_2, nvPM, NOx, sulfur)
- Consistent with other forecast modes of transportation

Requirements for aviation decarbonization

- Sustainable production
- Scalability
- Manageable cost

Safety is non-negotiable in every step of technology development and implementation

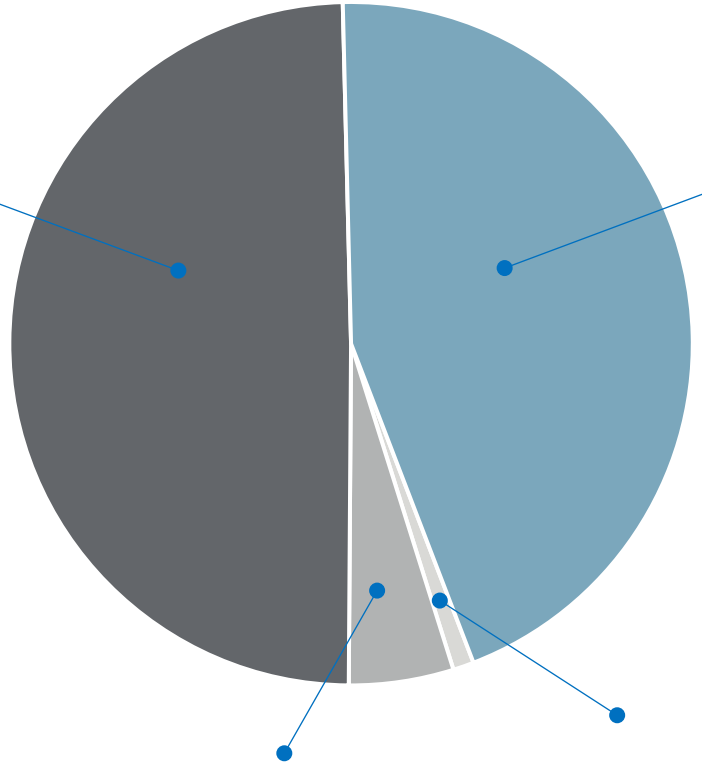
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Impacting the commercial fleet

Global Fleet Fuel Consumption

(~100,000,000,000 gallons (380 Billion L) Jet-A per year

Widebody
5000nm typical mission
12-16 hours per day
Fewer airports
ETOPS up to 370 mins



Single-Aisle
6-8+ flights per day
Many airports
180 mins ETOPS

Regional Jets

GA, Commuter, Helicopters

Reducing emissions and energy use demands affecting Single-Aisle and Widebody markets

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A Few Key Challenges

Influencing aviation's footprint requires impacting Single-Aisle and Widebody fleets

Non-drop-in kerosene fuels

- All stakeholder concerns addressed
- Re-certification process manageable
- Sustainable production
- Scalability and distribution infrastructure
- Manageable cost

Non-drop-in non-kerosene fuels

- Predictability of fuel availability to allow optimization
- Experience to support commercial guarantees
- Certification processes
- Proving equivalent safety
- Achieving operational effectiveness, e.g., ETOPS
- Public acceptance, e.g., social media effect

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Cryogenic Fuels

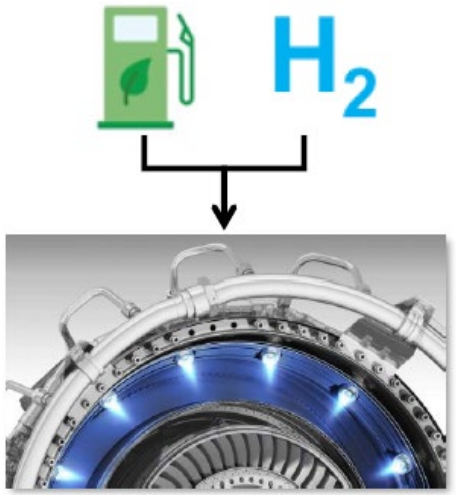
Strategy to secure long-term fuel options suitable for all market segments

- Advanced concepts to harness the potential of novel fuels
- Dual fuel concepts to bridge the transition

Dual fuel

- Enables cryogenic flight when available, but not required
- Gain real-world operating experience with new fuels

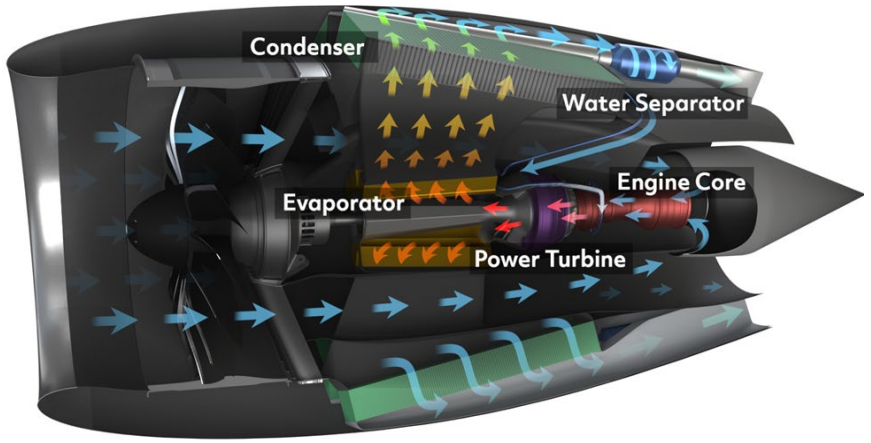
HyADES



Fuel-optimized propulsion systems

- Leverage unique properties of liquid hydrogen
- Maximize economic and environmental potential

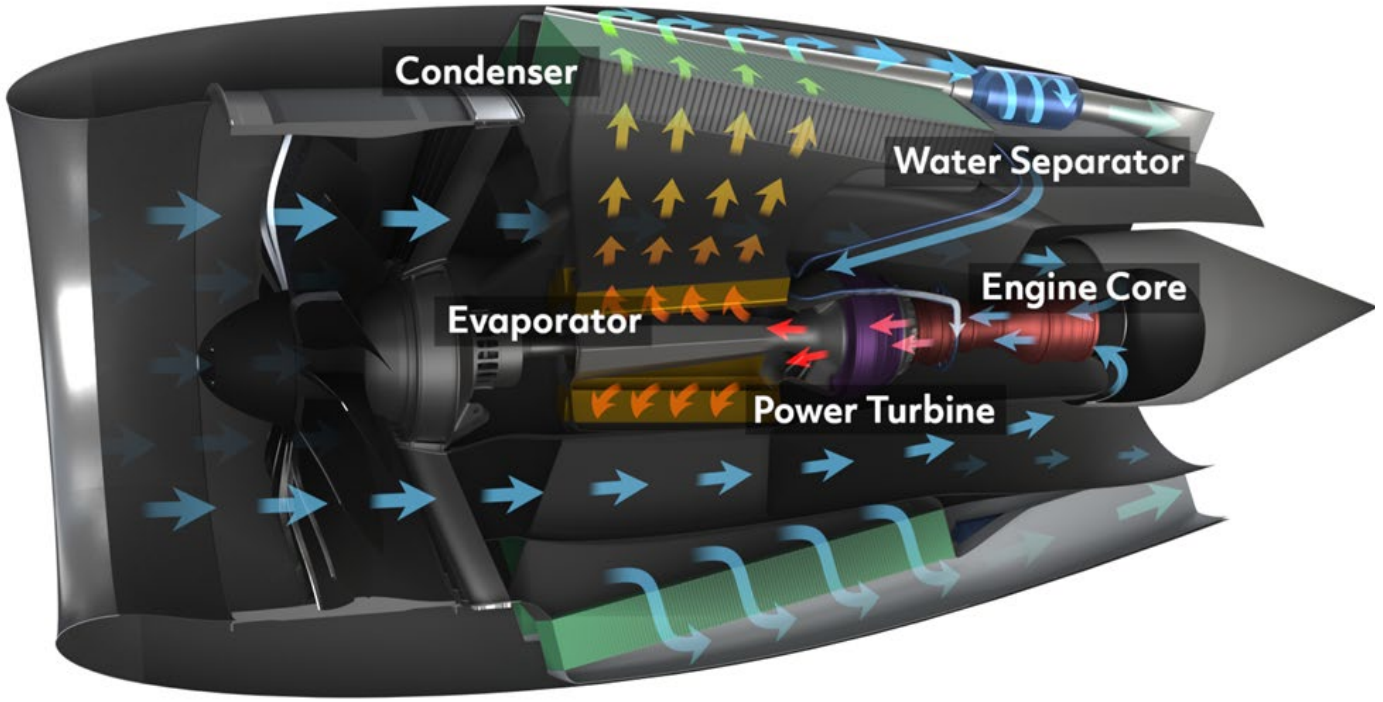
HySIITE



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Cryogenic fuels pose large opportunities & challenges

Hydrogen Steam Injected Intercooled Turbine Engine (HySIITE)



Opportunities:

- Waste Heat Recovery
- Leverage cold heat sink
- Lower environmental impacts
- Steam cycles
- Superconducting electronics

Challenges:

- Combustion systems
- Fuel Heating
- Fuel Pumping / Metering
- Fuel Safety / Leakage
- Off-design operation
- Unknown-unknowns

Potential for substantial (>30%) efficiency improvement; demands substantial development

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Fuel burn is not the only consideration

HySIITE was evaluated alongside other concepts in a broad trade study, within the context of 3 future scenarios

Criteria considered:

- Mission CO_2
- Contrails
- Human health impact of emissions, incl. NO_x
- Noise
- Fuel Cost
- Engine Maintenance
- Manufacturing Cost
- Airport infrastructure needs
- Development cost
- Airframe integration
- Scalability across size-classes
- Climate resilience
- Proliferation potential

Scenario 1

No significant use of sustainable fuels

Abundant, cheap fossil fuel

	Price $/gal JFE	Carbon intensity
Jet-A	$2.50	1
H_2	$6.00	1.25

Scenario 2

50% of kerosene is sustainable, increases average price

H_2 is mostly renewable, but expensive

	Price $/gal JFE	Carbon intensity
Jet-A	$4.50	0.6
H_2	$5.50	0.1

Scenario 3

100% sustainable fuels

Sustainable fuels are cheaper than scenario 2, but fuel price goes up due to higher blending ratio

	Price $/gal JFE	Carbon intensity
SAF	$5.00	0.1
H_2	$4.00	0

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Social metric weighting was swept to understand sensitivity to uncertainty

Scenario 1

No significant use of sustainable fuels

Abundant, cheap fossil fuel

Scenario 2

50% of kerosene and natural gas are sustainable, increases average price

H_2 is mostly renewable, but expensive

Scenario 3

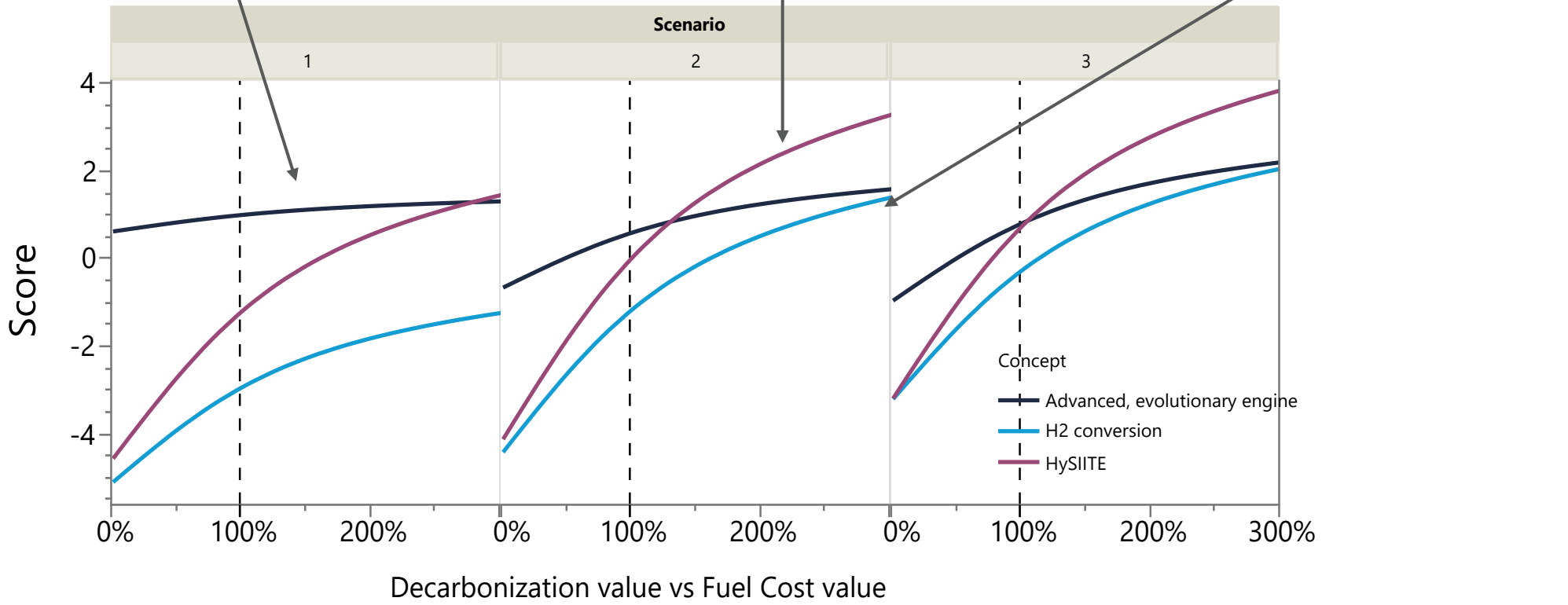
100% sustainable fuels

Sustainable fuels are cheaper than scenario 2, but fuel price goes up due to higher blending ratio

The advanced, evolutionary engine is hard to beat in some scenarios

Despite associated complexity & risks HySIITE wins in other scenarios due to significant benefits

Direct H_2 conversion doesn't trade well in the single-aisle seat-class



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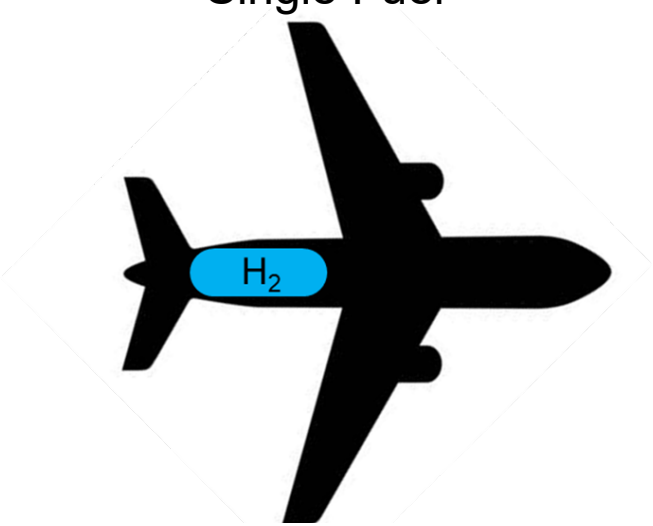
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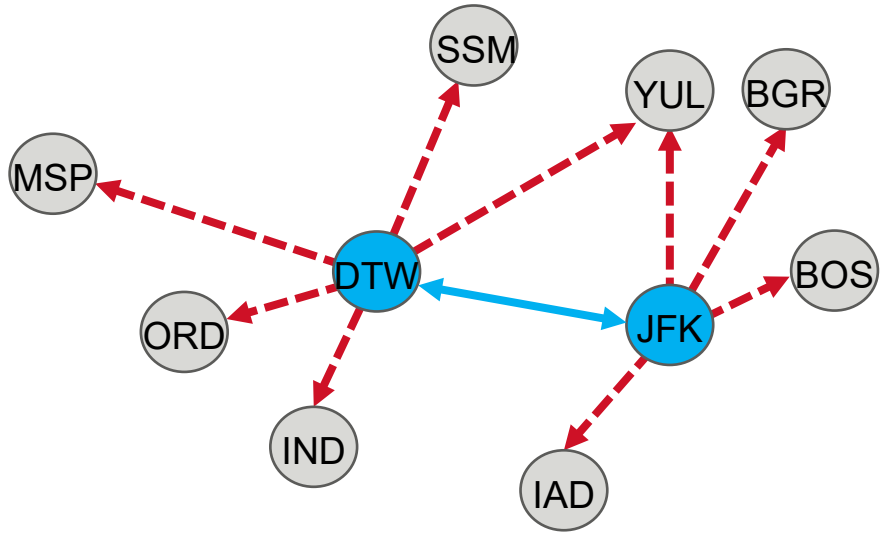
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How do you overcome the experience & infrastructure risk of H_2?

Single Fuel



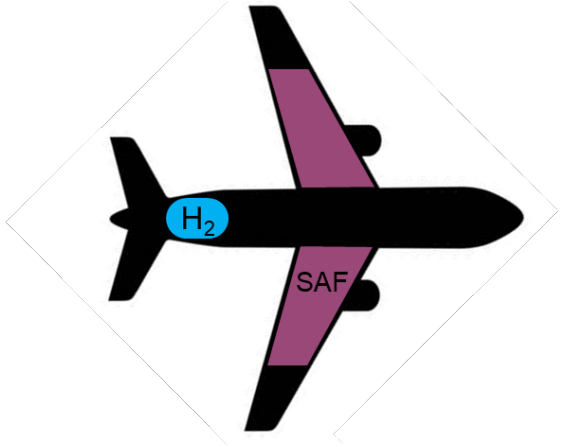


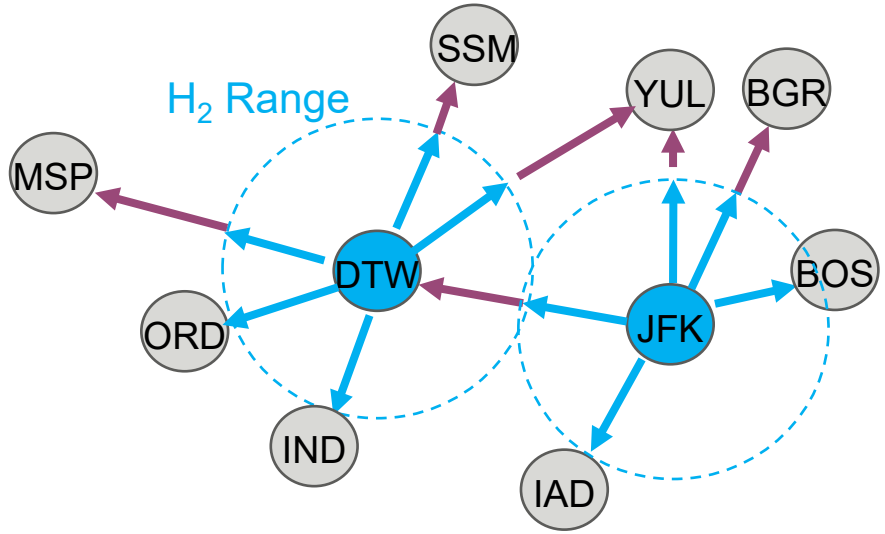
2 airports with H_2 → one H_2 flight

Severe operational constraints

Problems handling diversions

Multi-Fuel





2 airports with H_2 → many flights

No operational constraints

More H_2 used

200 NM of H_2 range on an 800 NM range aircraft can displace 75% of the fleet fuel with H_2

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HYADES – Hydrogen Advanced Engine Study



Techno bricks & ground Demo

Multi-year project

Supported by INSAT

Supports 2050 Net Zero

Next Hydrogen partnership

Leverages PW127XTH as proven engine

Address Infrastructure challenges

Non-CO_2 emission mitigation

Phased approach

Achieving H_2 Ground testing and Multi-Fuel Investigation

Collaborators:	**INSAT**	**Next Hydrogen Solutions Inc**

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Large Engine Multi-Fuel Hydrogen Combustion

Preparing to launch in January 2027



Pratt & Whitney is preparing to launch a multi-year research program in the Netherlands

The program supports technology maturation in multi-fuel (hydrogen, SAF) combustion, LH_2 fuel preconditioning and LH_2 fuel system aircraft integration

Led by Pratt & Whitney's European Technology & Innovation Center (ETIC)

Collaborators: GKN, TU Delft, nlr, materialise, PHOTONFIRST, Somni, ADSE CONSULTING AND ENGINEERING

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Conclusions

Answering aviation's long-term fuel question requires solutions for Single-Aisle and Widebody fleets

SAF is a lower technical risk solution but poses production and cost challenges

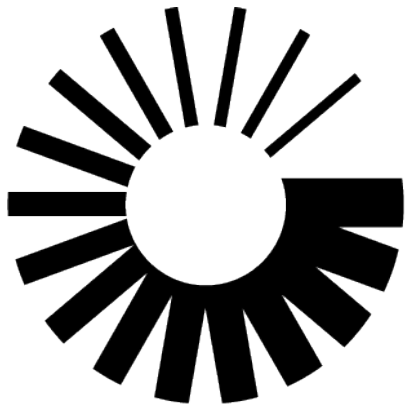
Novel fuels require advanced concepts enabled by fuel properties, like HySIITE

- Deliver cost efficient solutions at single-aisle and widebody scales
- Enable benefits to outweigh risks of infrastructure needs and development costs

Multi-fuel provides a potential steeping-stone to gain experience and support transition between fuels

- 75% of regional turboprop fleet fuel burn could be displaced with only 200 NM of H_2 range capability
- More flights can use H_2 with incomplete infrastructure

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Engine OEM Role in SAF Qualification

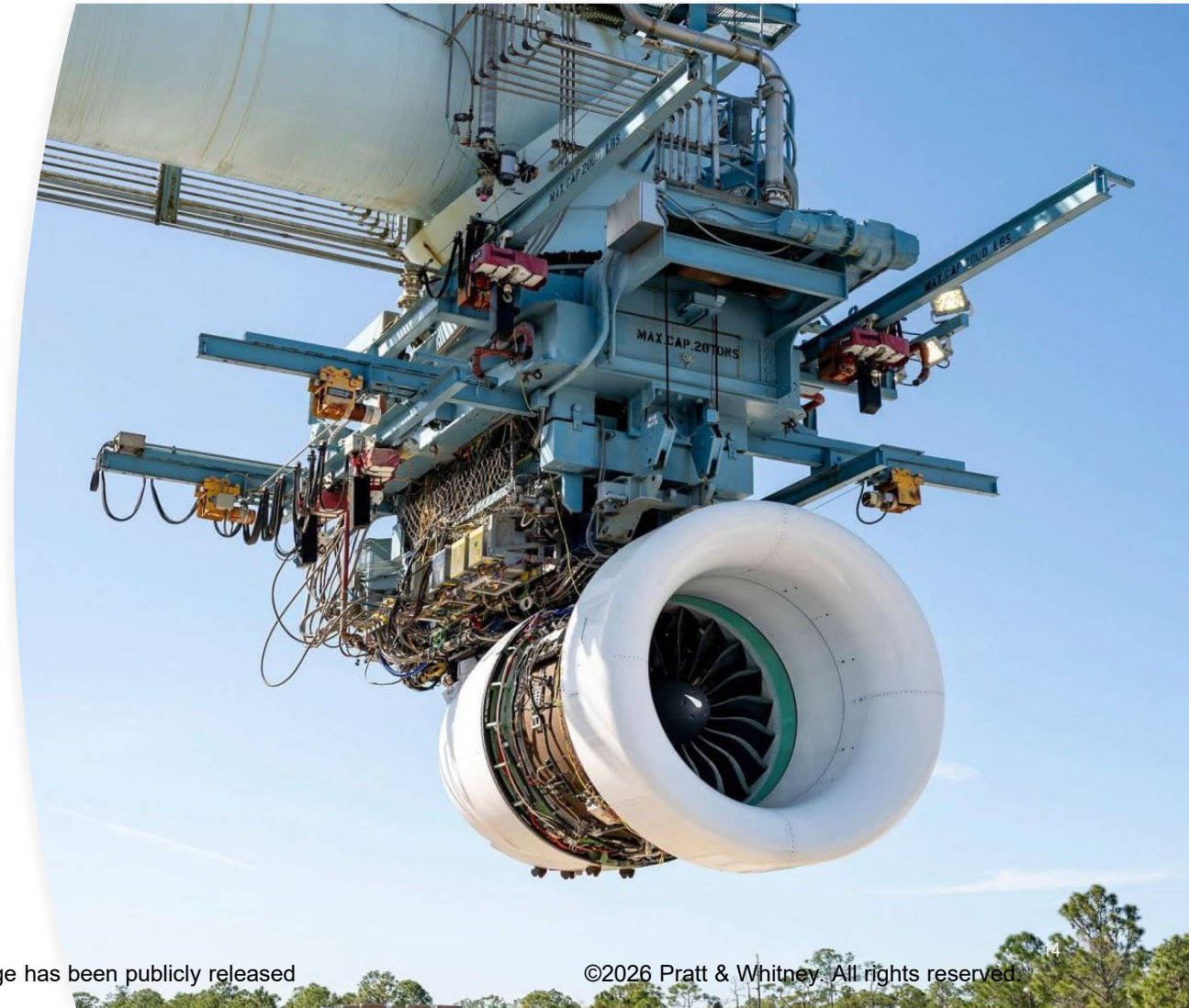
SAF is a lower technical risk solution but poses production and cost challenges

OEM actions to validate alternative fuels

- Evaluate candidate fuels for “fit-for-purpose” properties
- Conduct technical / performance evaluation on the engine
- Provide timely feedback through ASTM balloting and approval process
- Offer industry support and policy advocacy

ASTM D4054

“Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives”



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