中国航发湖南动力机械研究所
AECC HUNAN AVIATION POWERPLANT RESEARCH INSTITUTE

High-blend Ratio SAF Validation and Challenges in HAPRI Aero-engine

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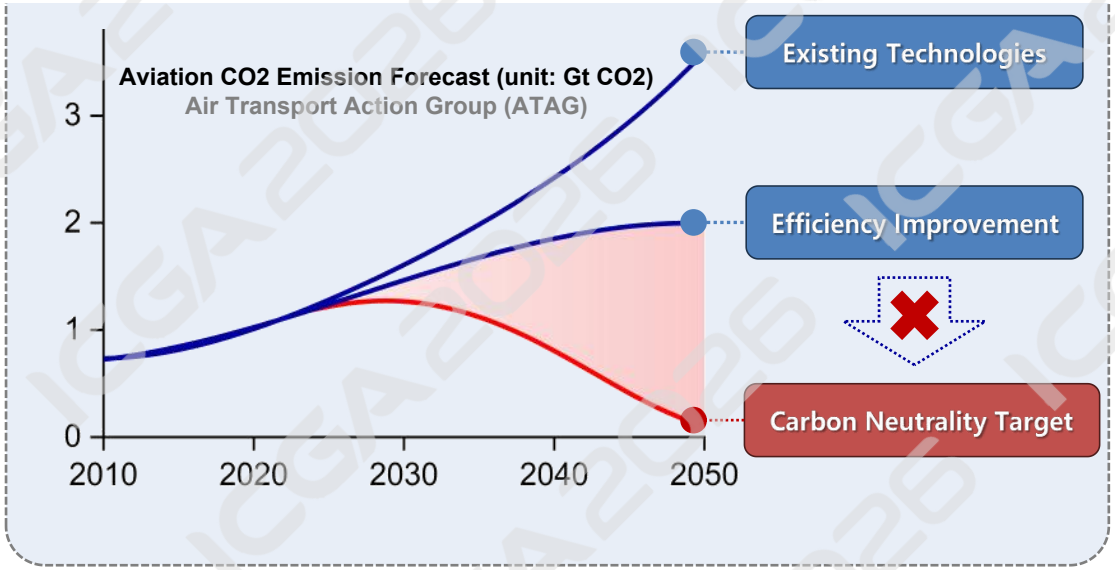
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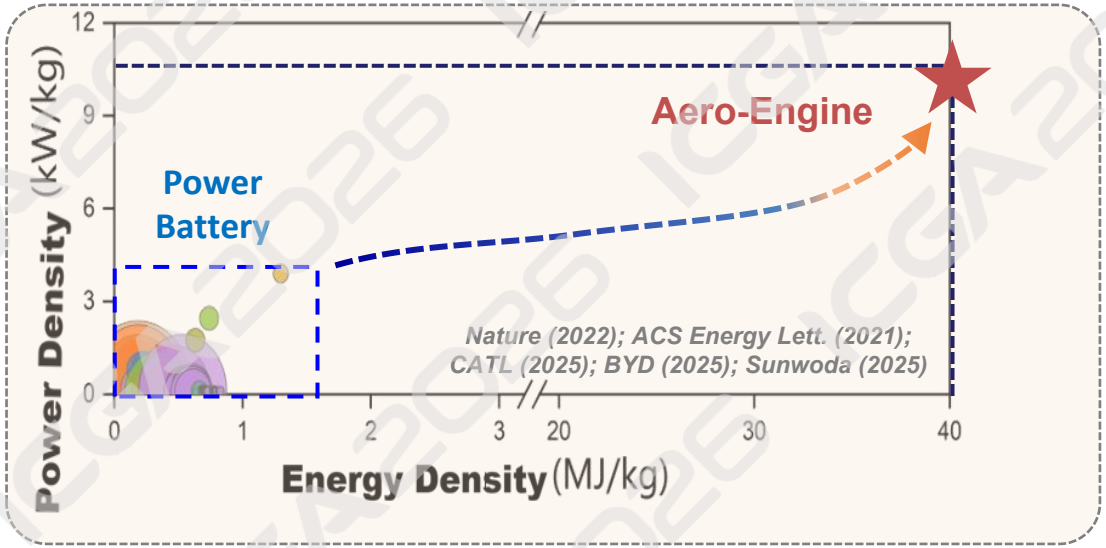
Research Background

I. Research Background

Aviation Decarbonization

Is there a technical path that combines existing technologies and enables rapid decarbonization?





Jet Fuel: Efficiency Improvement of Existing Engines

"Carbon Neutrality Gap"

All-Electric / All-Hydrogen: R&D of All-New Engine Configurations

"A Long and Arduous Journey Ahead"

I. Research Background

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Technical Path: Existing Aero-Engine Technologies + Sustainable Aviation Fuel (SAF)



Strategic Value

Diverse feedstocks, green and low-carbon
Facilitating aviation decarbonization

Emergency fuel, domestic supply security
Safeguarding national defense security

I. Research Background

- **China has abundant raw materials available for SAF production, with a theoretical of up to 46.41 million tons per year. The future development prospects are enormous.**

Feedstock	Availability (10,000 t/yr)	SAF Output Ratio	SAF Production (10,000 t/yr)
Waste cooking oil	340	40% (HEFA)	136
Agricultural waste	20,700	10% (AtJ or G+FT)	2,070
Forestry waste	19,500	10% (AtJ or G+FT)	1,950
Municipal organic solid waste	2,350	10% (AtJ or G+FT)	235
Ethanol from industrial waste gas	500	50% (AtJ or G+FT)	250
Total	43,390	–	4,641

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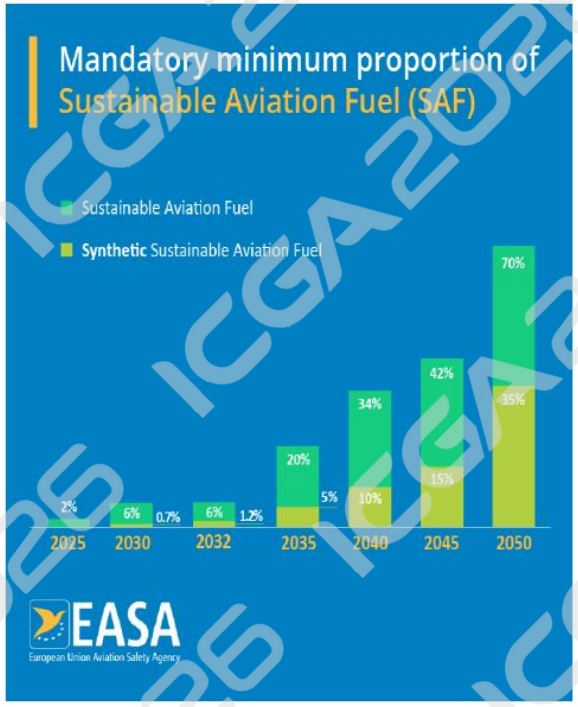
Governments Worldwide Promote the SAF Industry

2022: U.S. DOE, DOT, USDA and EPA



- SAF output of 9 million tonnes by 2030
- SAF output of 100 million tonnes by 2050

2023: EU enacts regulations ReFuelEU



- SAF share no less than 6% by 2030
- SAF share no less than 70% by 2050

2023: China’s MOST, MIIT, MOF and CAAC



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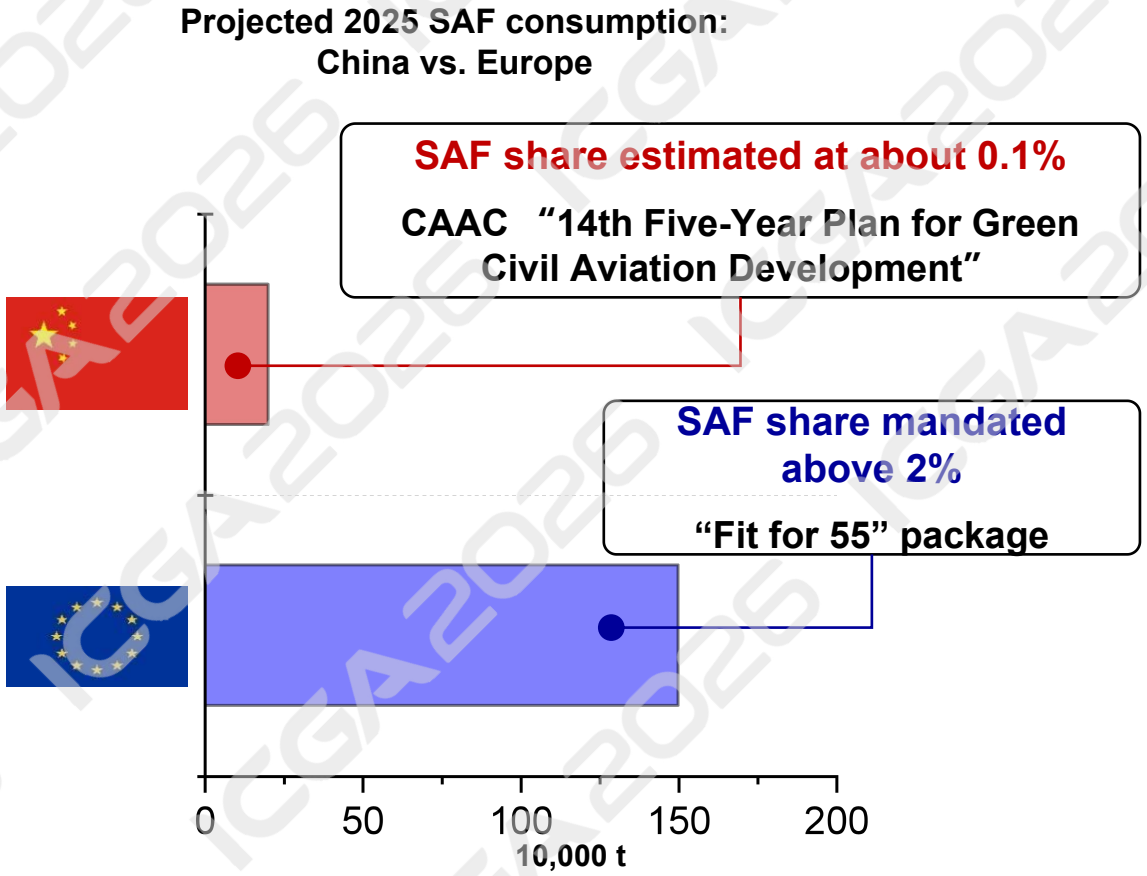
本报讯（记者 罗晓燕）“面向全球航空业绿色低碳转型与我国能源安全战略需求，需建设国产航空替代燃料发动机中试基地。”全国两会期间，全国人大代表、中国航发湖南动力机械研究所专职总师单晓明提出建议。

Source: Beihang Univ. (Advanced Aero-Engine Combustion Team)

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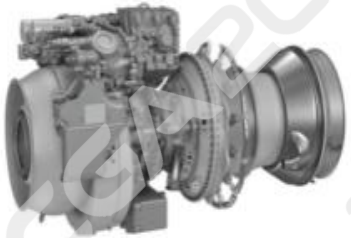
Europe and the U.S. Hold a Triple Advantage in SAF

Name	Process	
ATJ-SPK/A	Alcohol-to-jet synthesis with aromatics	
HEFA-SPK	Hydroprocessed esters and fatty acids	China GB 6537
FT-SPK	Fischer-Tropsch synthesis	
SIP-FHS	Synthesized iso-paraffins	
FT-SPK/A	Fischer-Tropsch synthesis with aromatics	
ATJ-SPK	Alcohol-to-jet synthesis	United States ASTM D7566 (8 certified routes)
CHJ	Catalytic hydrothermal conversion	
HC-HEFA	Hydroprocessed hydrocarbons, esters and fatty acids	



I. Research Background

■ Overseas Aero-Engine SAF Research: Blend Ratio up to 100%

	R&D Testing	Ground Testing	Flight Testing
 Turboshaft	•GE CT7-8（VTOL Vy400）	•Safran Arriel 2E 100%SAF（H145） •Safran Arreno 38%SAF（H160）	•Safran Arriel 2E 40%SAF（H145） •Safran Makila 100%SAF（H225） •Safran Aneto-1K（AW149）
 Turboprop	•GE Catalyst（Business Jets） •PW127XT 100%SAF •（Regional Jet ATR42/72）		
 Turbofan	•Rolls-Royce Pearl 10X 100%SAF（Business Jets） •PW GTF Advantage 100%SAF（A320neo）	•Rolls-Royce Pearl 700 100%SAF（Gulfstream G700） •PW PW1900G 100%SAF（E195-E2）	•Rolls-Royce Trent 1000 100%SAF（B747-200） •Rolls-Royce Trent XWB 100%SAF（A350） •GE GE90 100%SAF（B777-300ER） •Safran CFM LEAP-1A 100%SAF（A320neo）

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China Actively Advances SAF Application and Flight Demos

- Airlines such as Air China, China Eastern and Hainan Airlines have conducted SAF test flights, but have not yet adopted routine refueling
- COMAC completed flight demonstrations of the C919 and ARJ21 using domestic SAF at 40% blend ratio
- AECC conducts component / whole-engine application evaluation on platforms of its self-developed civil turboshaft and turbofan engines
- Domestic Institution and Universities have carried out research on production processes, physicochemical properties, model combustor tests, life-cycle assessment models and safety impacts



C919 SAF flight demo



AECC AES100



AECC CJ1000



GIEC 1,000 t/y bio-jet fuel demo unit

02

Introduction to the HAPRI

II. About HAPRI

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AECC Hunan Aviation Powerplant Research Institute (AECC HAPRI): China's Only R&D Base for Small-Medium Aero Engines & Helicopter Transmissions.

- Turboshaft and Turboprop Engine Research and Development Center
- R & D Center for Small and Medium-sized Turbofan and Turbojet Engines
- R & D Base for Auxiliary Power Units and Starters
- R & D Base for Helicopter Transmission Systems





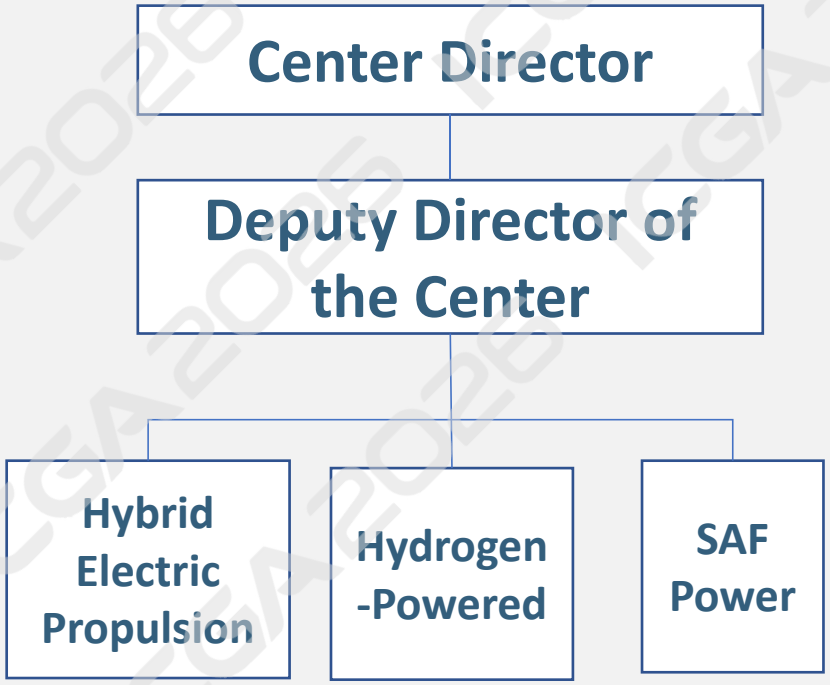


II. About HAPRI

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In 2023, Hunan Green Aviation Power Tech Center established leading green aviation tech & industry innovation. Using the AES100 turboshaft engine, validation of 10%, 50%, and 100% SAF blends in engine combustors has been conducted.





Organizational Framework

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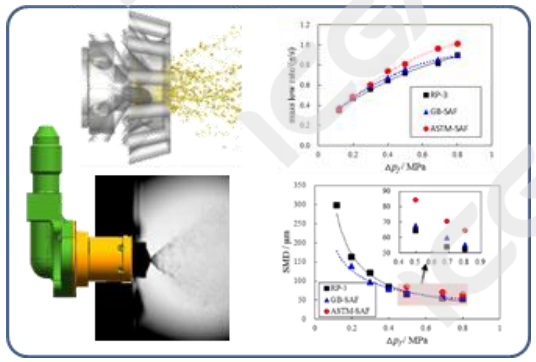
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Research Capability

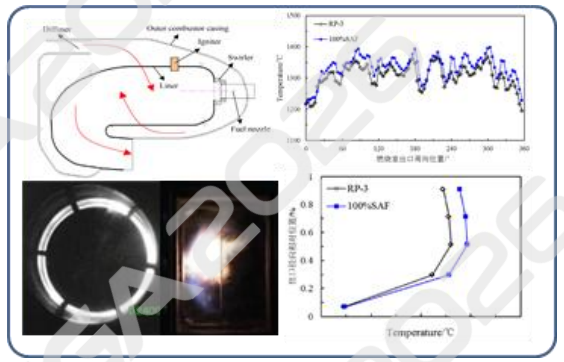
HAPRI Has Complete Fuel Performance Evaluation Capability

- Completed verification of combustor and the fuel system for SAF at 10%–100% blends, established a SAF evaluation system based on “part–component–system–whole engine” framework, and supported the self-developed AES100 engine in completing ground performance validation with 92% blend ratio SAF.

Part Level



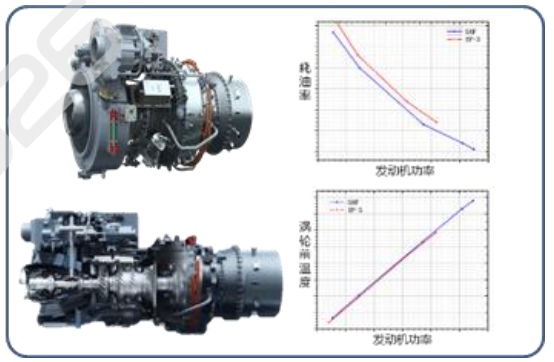
Component Level



System Level



Whole-Engine Level



II. About HAPRI

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- Research and assessment test and measurement facilities covering the entire combustor / engine R&D process have been established, providing complete validation capability

For comprehensive part-level and component-level tests of fuel nozzles, swirlers, single domes, etc.

- Fuel Nozzle and Manifold Integrated Test Rig
- Slinger Performance Test Rig
- Combustor Component Integrated Test Rig
- Combustor Multi-Dome Test Rig

For full-parameter performance tests, thermal fatigue tests and high-altitude / plateau ignition tests of combustors

- Low-Pressure Combustor Test Rig
- Medium-Pressure Combustor Test Rig
- High-Temperature High-Pressure Combustor Test Rig
- Combustor High-Altitude Ignition Test Rig
- Combustor Thermal Fatigue Test

03

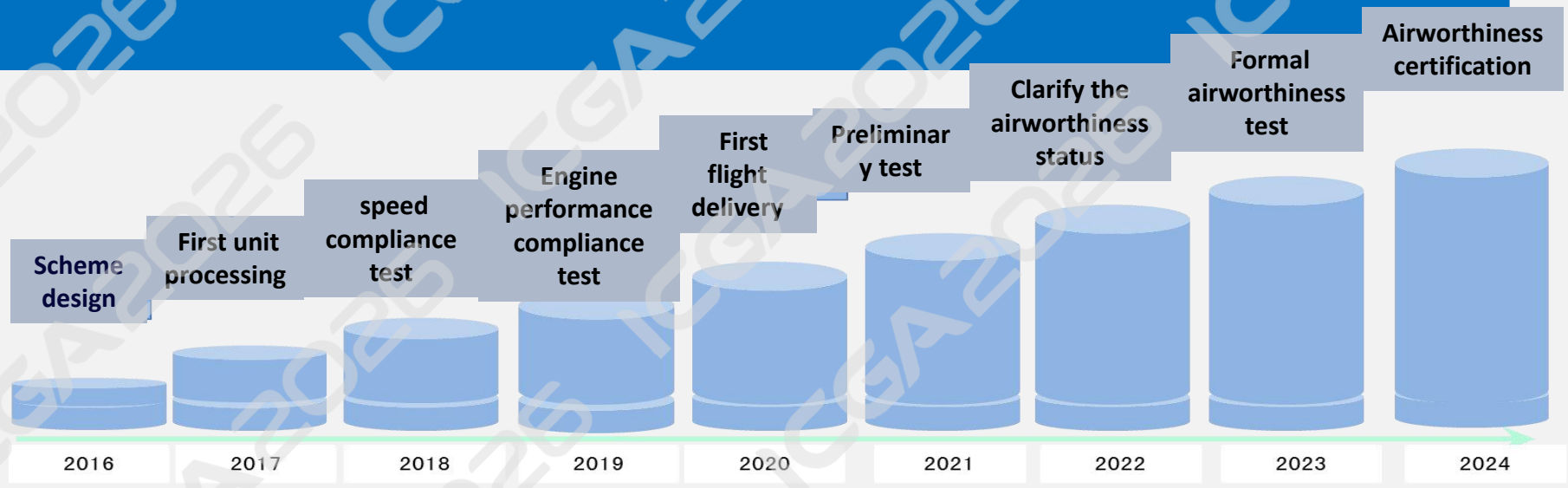
High-blend Ratio SAF Validation

Engine platform for SAF verification: AES100

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The verification platform is the AES100. It is China's first domestically developed advanced turboshaft engine. Through the development of the AES100 engine, we have independently completed the whole airworthiness certification process for civil turboshaft engines and filled the gap of domestically produced advanced civil turboshaft engines. It meets the power demands of 5–6 ton twin-engine helicopters and 3–4 ton single-engine helicopters, and completed airworthiness certification in August 2024.





SAF test in combustor rigs

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The fuel used in this study was produced by Henan Junheng using the HEFA process and is 100% SAF.





Parameters	Values	
	SAF	RP-3
Calorific Value/(MJ/kg)	44.1	43.5
Density(20℃)/(kg/m^3)	764.8	783.3
Kinematic Viscosity(20℃)/(mm^2/s)	2.7	1.6
Surface Tension(20℃)/(mN/m)	25.4	24.9
Flash Point/℃	49.0	44.0
Final Distillation Point/℃	285.0	239.5
Naphthene Mass Fraction/%	0.3	14.5
Hydrogen-to-carbon Ratio	2.134	1.889

III. Application Validation

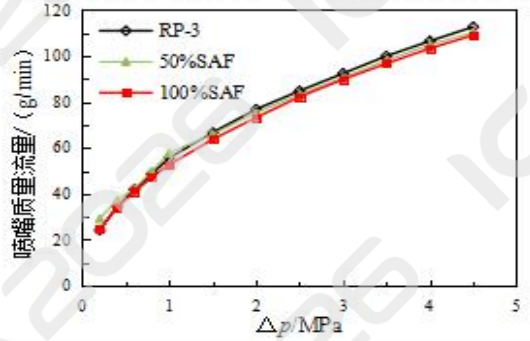
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Validation

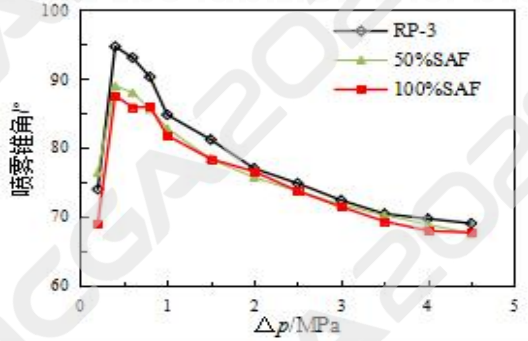
Atomization Test | Cold Ignition Test | Combustor Test | Ground Test

- At normal temperature, SAF and RP-3 show comparable spray performance
- (nozzle flow rate, spray cone and SMD)
- At low temperature, no effective atomization mode at the ignition fuel pressure

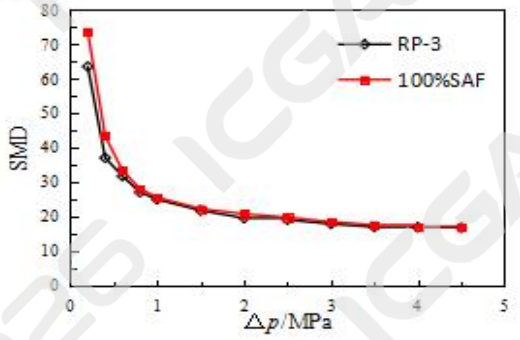
Normal temp. condition



● Nozzle Flow Rate

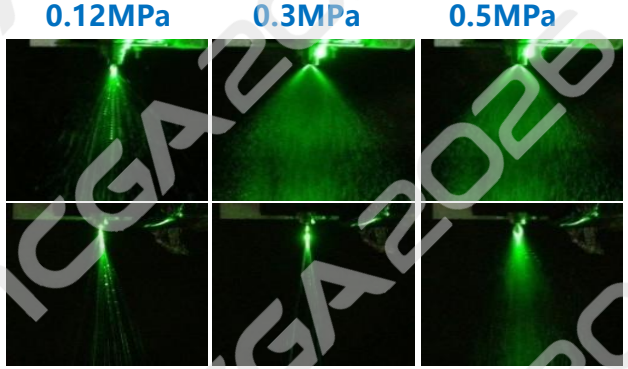


● Spray Cone Angle

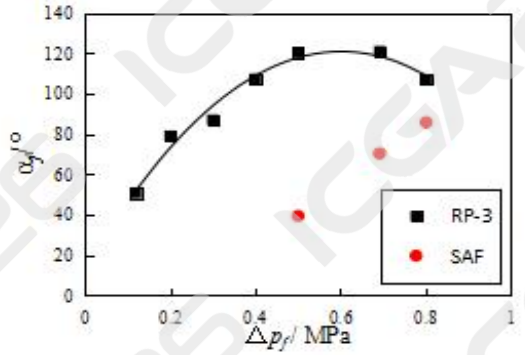


● Particle Size

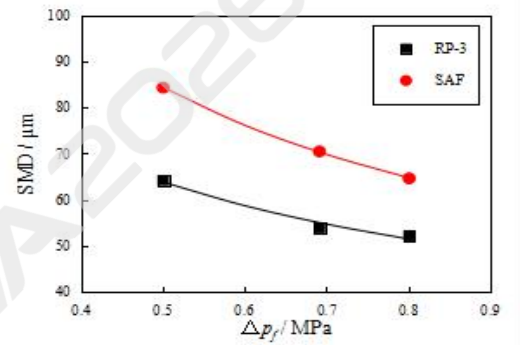
-20℃ condition



● Low-Pressure Spray



● Spray Cone Angle



● Particle Size

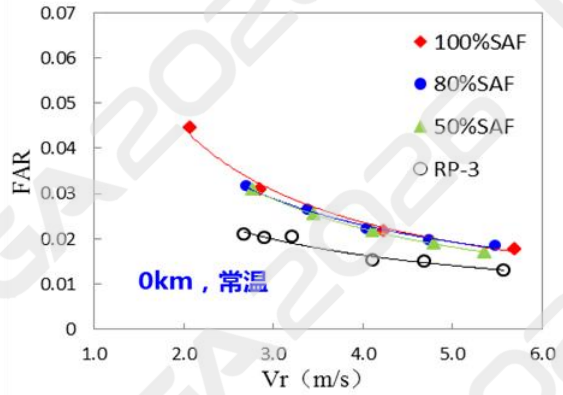
III. Application Validation

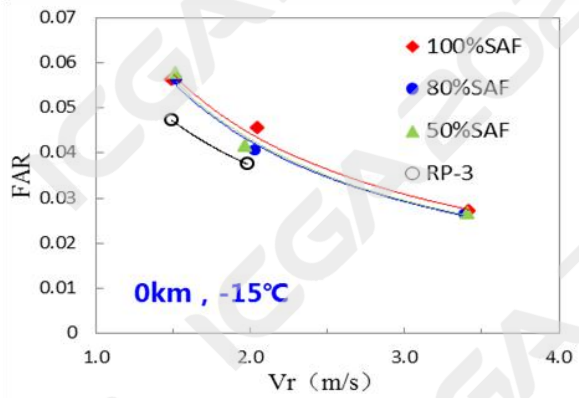
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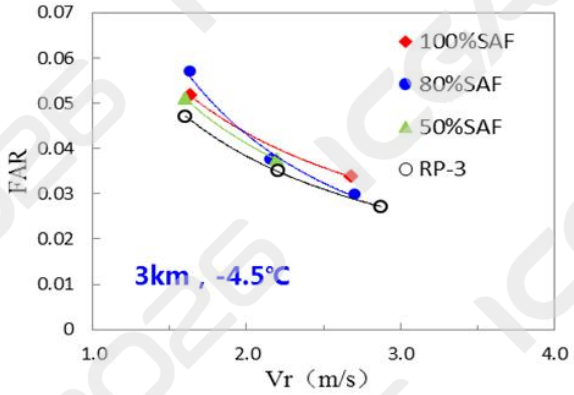
Validation

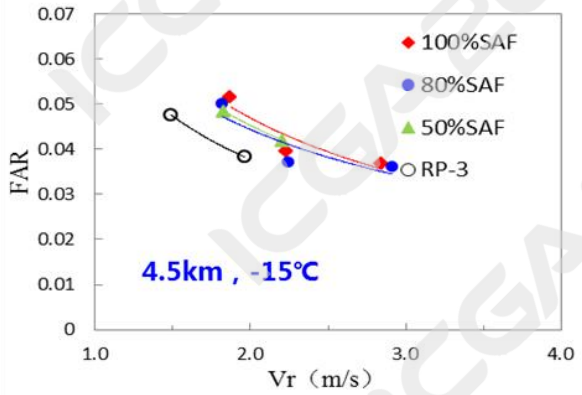
Atomization Test | **Cold Ignition Test** | Combustor Test | Ground Test

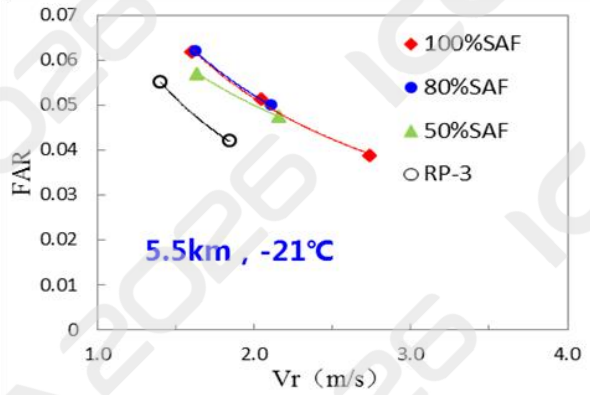
Temperature drops below -20°C, SAF at blend ratios of 100%, 80% and 50% all fail to achieve successful ignition. Ignition capability under high-altitude cold conditions is inferior to that of RP-3.











Test condition	100%SAF	80%SAF	50%SAF	RP-3
0 km, normal temp.	√	√	√	√
0 km, -15°C	√	√	√	√
3 km, -4.5°C	√	√	√	√
4.5 km, -15°C	√	√	√	√
5.5 km, -21°C	√	√	√	√
0 km, -40°C	X	X	X	√
4.5 km, -40°C	X	X	X	√
5.5 km, -40°C	X	X	X	√

Ignition failure

III. Application Validation

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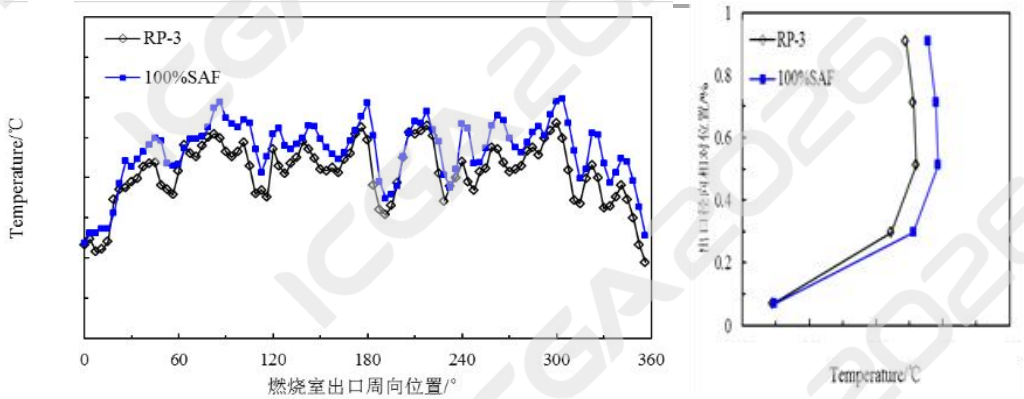
Validation

Atomization Test | Cold Ignition Test | **Combustor Test** | Ground Test

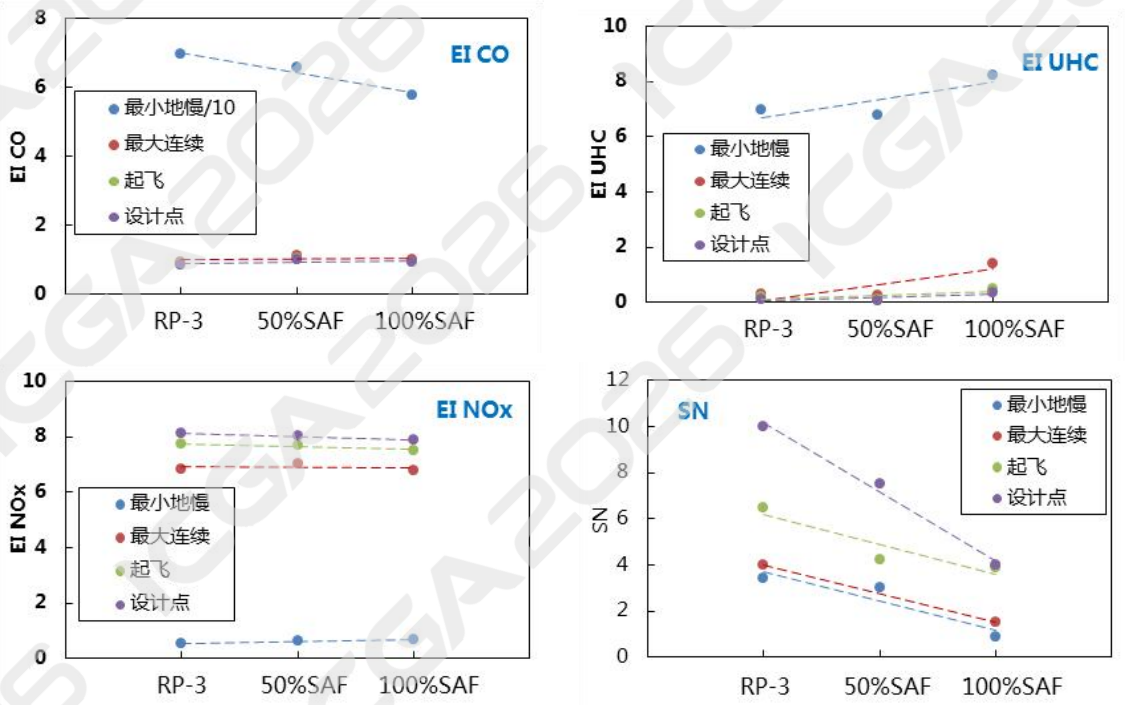
- Steady-state performance parameters (combustor OTDF, RTDF and combustion efficiency)are basically comparable to those of RP-3 (Tt4 about 30℃ higher than RP-3).
- Substantial reduction in smoke emissions (-47%)

Combustor performance data

Fuel type	Tt4(℃)	OTDF	RTDF	Combustion efficiency
RP-3	T	0.145	0.061	0.999
SAF	T+30	0.155	0.064	0.999



Combustor emission data



III. Application Validation

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Validation

Atomization Test | Cold Ignition Test | Combustor Test | **Ground Test**

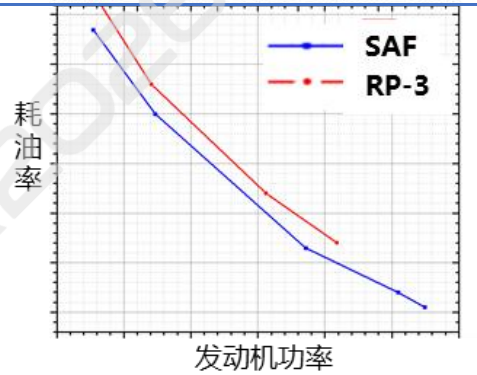
- In December 2024, the AES100 engine completed ground performance validation(92% SAF)
- At the same corrected power, engine performance parameters with SAF are basically comparable to those with RP-3



Engine performance parameters

Parameter variation at the same corrected power	
Specific fuel consumption (kg/kW/h)	**-0.0045**
Turbine inlet temperature (°C)	**+2.3**





III. Application Validation

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Summary

SAF: Good Steady-State, Poor Low-Temperature Compatibility

- Combustion performance under steady-state conditions is basically comparable to RP-3, with no obvious impact on existing engine performance
- Differences in physical properties and composition from jet fuel affect reactivity (ignition, flame propagation), degrading ignition performance and increasing sensitivity to extreme conditions



Physicochemical Properties	HEFA-SAF	RP-3
Calorific Value/(MJ/kg)	44.1	435
Density(20℃)/(kg/m^3)	764.8	783.3
Kinematic Viscosity(20℃)/(mm^2/s)	2.7	1.6
Kinematic Viscosity(-20℃)/(mm^2/s)	9.2	3.1
Surface Tension(20℃)/(mN/m)	25.4	24.9
Flash Point/℃	49.0	44.0
Final Boiling Point/℃	285.0	239.5
Naphthenic Mass Fraction/%	0.3	14.5
Carbon-to-Hydrogen Ratio (C/H Ratio)	2.134	1.889

Low-temp viscosity

Composition gap





工况条件	SAF	RP-3
0 km、25°C	√	√
0 km、-15°C	√	√
3 km、-4.5°C	√	√
4.5 km、-15°C	√	√
5.5 km、-21°C	√	√
0 km、-40°C	X	√
4.5 km、-40°C	X	√
5.5 km、-40°C	X	√

Under cold conditions, SAF ignition start-up fails

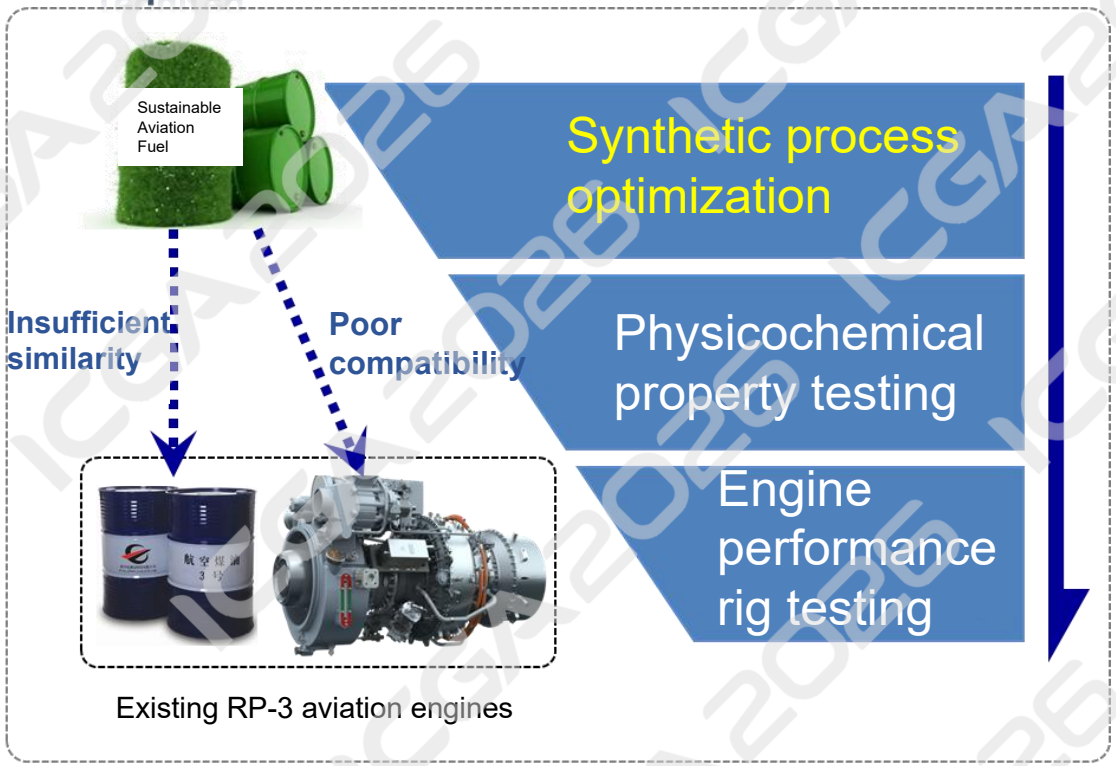
Insufficient similarity to jet fuel → poor matching with existing engine → maximum blend ratio limited to 50%

04

Challenges and Expectations

Limited SAF Blend Ratio and High Cost Hinder Wider Use

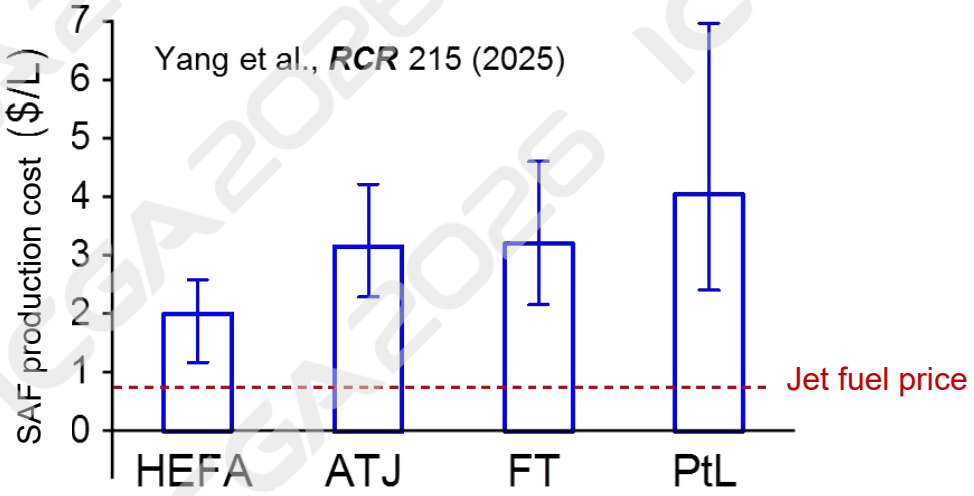
- To improve the matching of SAF with existing RP-3 aero-engines, extremely high similarity between SAF and jet fuel is required



High process cost, 50% blend limit

Drop-in SAF

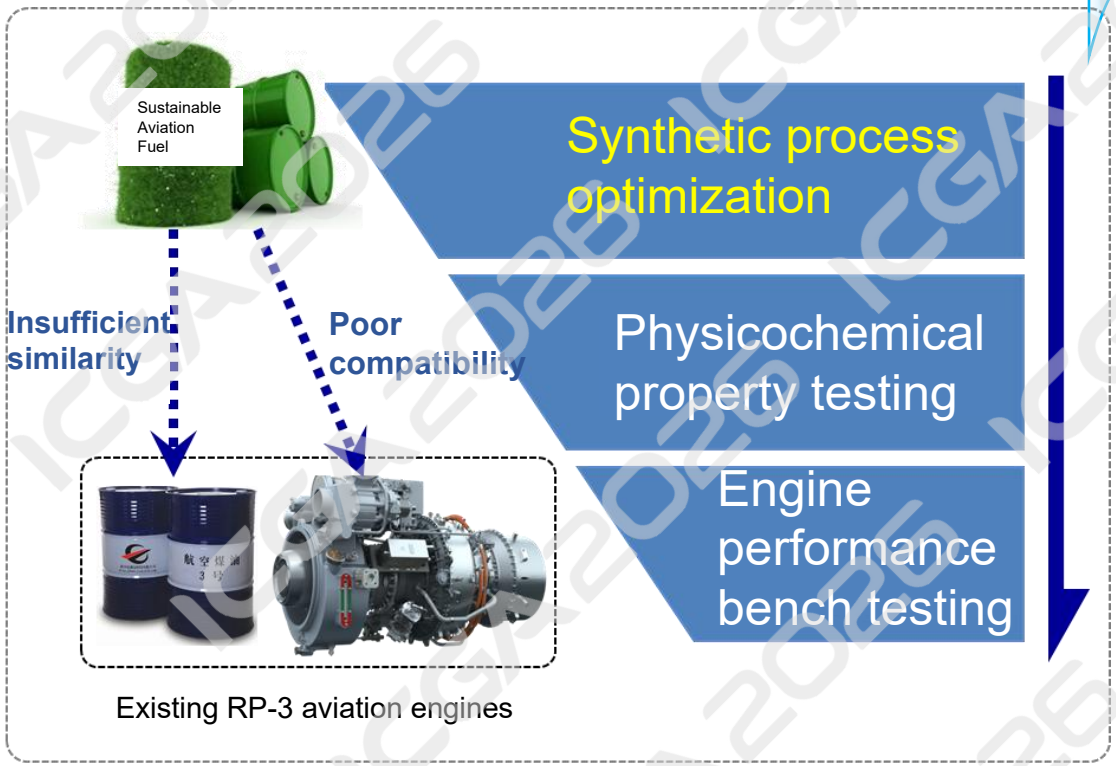
- Currently, the cost of SAF is 3–5 times that of conventional jet fuel
- High requirements for synthesis processes further increase costs



IV. Challenges

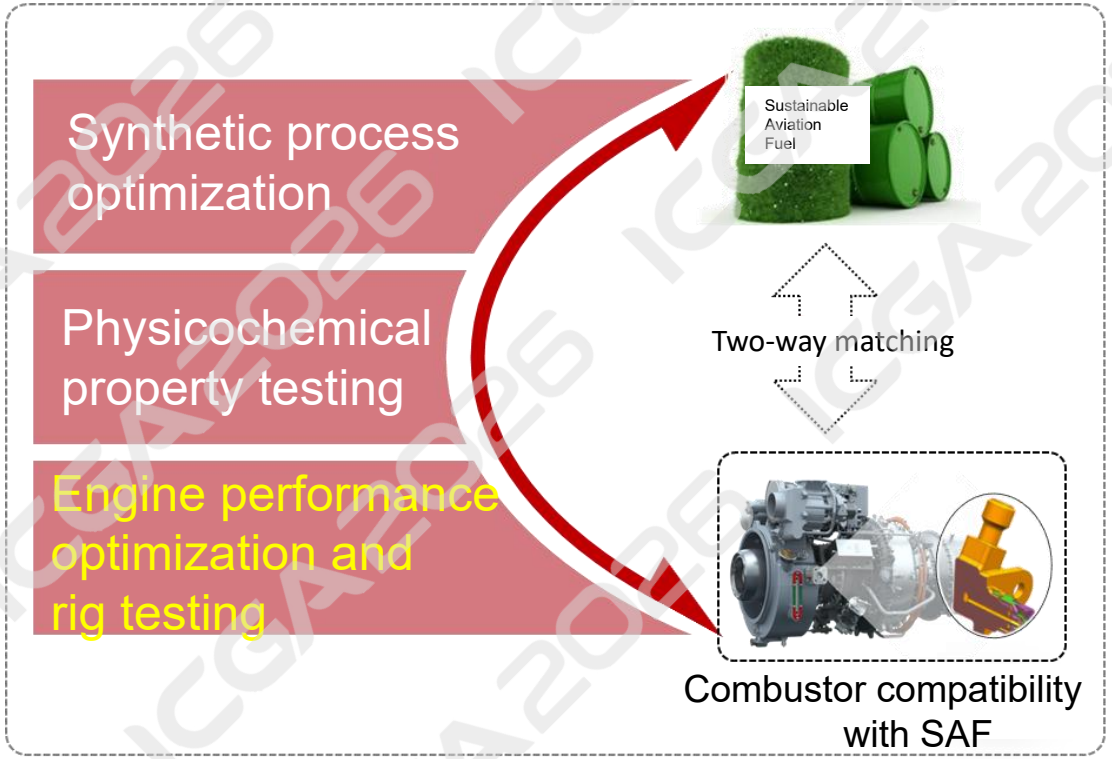
Development Proposal

"Drop-in" SAF: tailoring the "fuel" to the "engine"



High process cost, 50% blend limit

"Non-drop-in" SAF: co-matching of "engine" and "fuel"



Lower process cost, remove usage restrictions

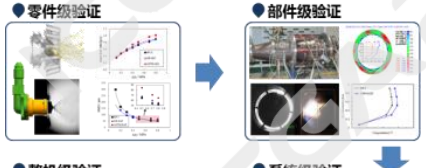
Collaboration Vision

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We sincerely look forward to working with domestic and international stakeholders focusing on full-chain innovation of SAF from "production" to "application".

Complete fuel performance evaluation & validation

- Complete validation system: a four-level "part–component–system–whole engine" validation system has been established
- Complete validation capability: research and assessment test facilities for the whole combustor / engine R&D process



Mature supply-chain collaboration

- Close cooperative relationships have been established with upstream and downstream players in the SAF industry chain, including COMAC, the Second Research Institute of CAAC, GIEC (CAS), Henan Junheng, China Southern Airlines, Civil Aviation University of China and Beihang University, providing access to technical and fuel production line support

Unique advantages of small & medium engines

- Low cost: low fuel cost and low rig operation and maintenance cost make large-scale, repeated test validation possible
- Short cycle: a shorter cycle from test preparation to data acquisition enables rapid validation of the effects of various SAF formulations and blend ratios
- Low risk: research on small and medium engines keeps risk within a small scope, making troubleshooting easier even if problems arise



Thanks!



