Beyond CO2: Bio kerosene, engine emissions and technical constraints

25th April 2013. Brussels

Aircraft engine aspects: Chances and Constraints

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Presentation content

Fuel performance requirements - “constraints”

- Fuel as a high performance fluid and impact on engines
- Specification and management of change
- Quality and Deployment issues

Increasing availability of sustainable fuels and property modification – “chances”

- Evaluating the performance of novel fuels in comparison to standard fuels
- Challenging current specification limits which are primarily based upon experience

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Fuel criteria

Safety and operability issues

- *Energy density*
- *Chemical characteristics*

Environmental and social issues

- *Fuel lifecycle CO_2 emissions*
- *Change in land and water usage*
- *Feedstock competition with food crops*

Large-scale commercial production issues

- *Fuel technology maturity level*
- *Production capability and readiness level*

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Impact of fuel properties

Safety

Certification

Cost of Ownership

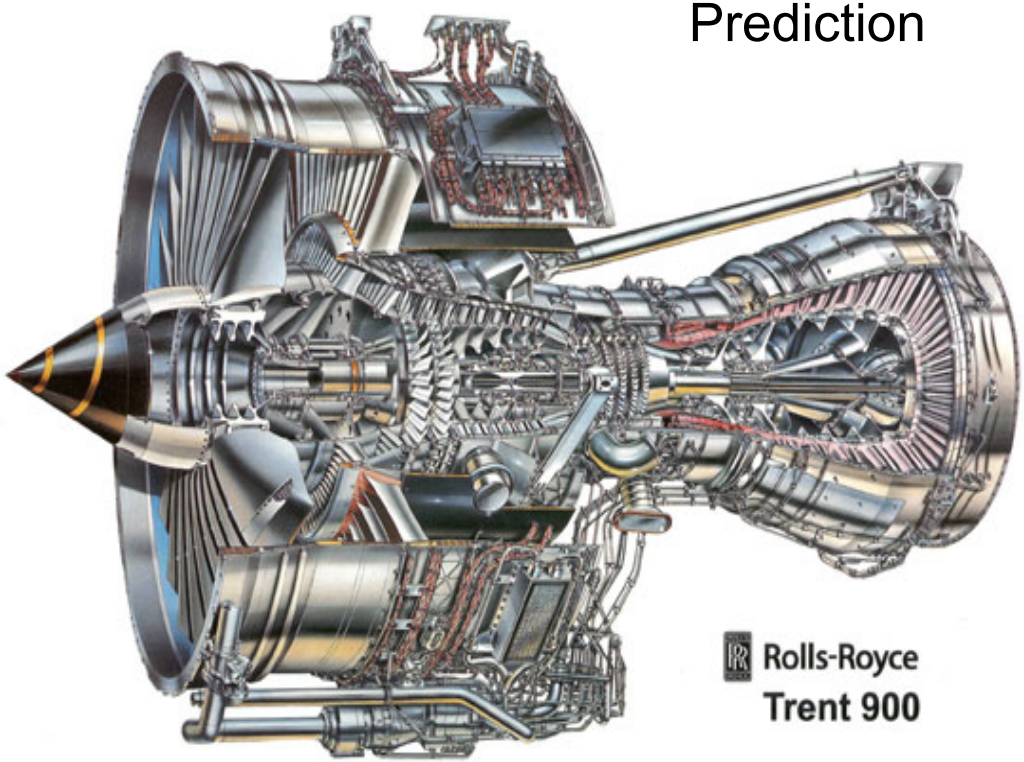
Durability

Performance

Maintenance

System Design & Materials

Future Technology



Legacy Hardware

Fluid Performance Prediction

Physical Properties

Deposition (coking)

Hot-End Life

Emissions

Cold Start & Alt re-light

Material Compatibility

Chemical Properties

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Designed for each other

Engine certification		*Fuel specification*
Operate on Jet A/A-1 fuels - World-wide standard *Ensure safety, emissions, performance and durability*	+	*Composition properties and performance* *Allowable source materials and processes* *Quality Assurance*

Fuel outside scope require testing and certification

Fuel has to be "drop-in" to be technically viable

Specifications <u>do not</u> test every critical parameter.

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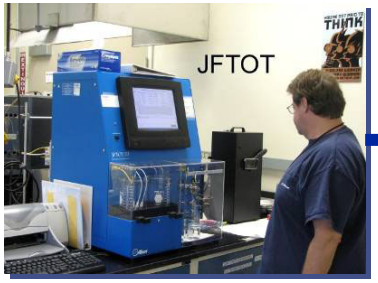
Industry qualification ASTM D4054 process



Specification Properties

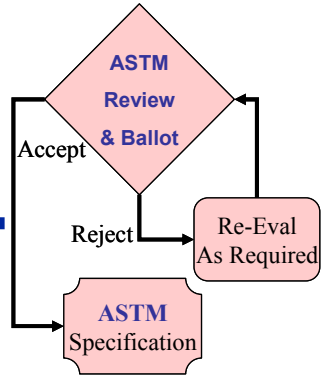
Fit-For-Purpose Properties

Component/Rig Testing

Engine/APU Testing

ASTM Research Report

FAA & OEM Review & Approval



ASTM Balloting Process

Def-Stan JP8/5…

Courtesy of Mark Rumizen, FAA – Note Some items added by Rolls-Royce

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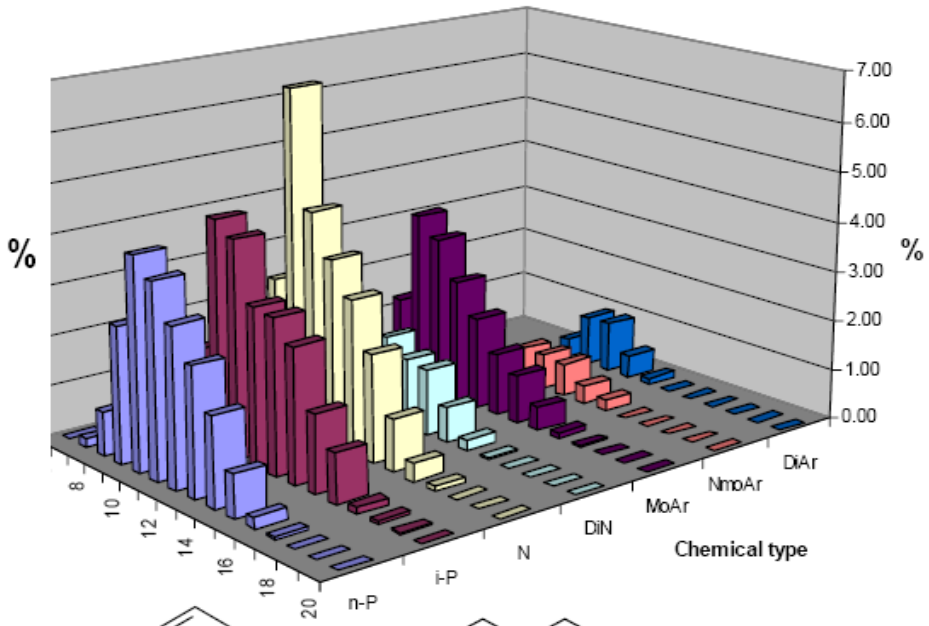
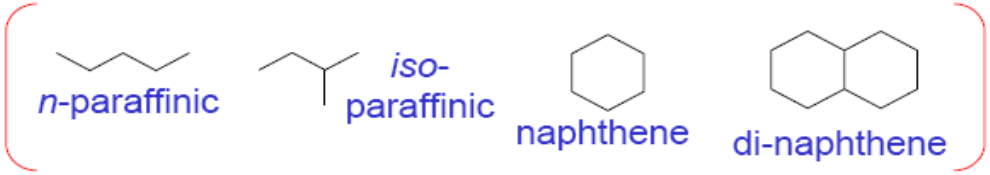
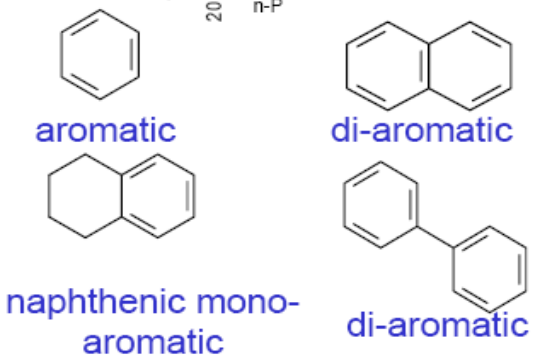
Fuel Composition

Typical UK Jet A-1 (ca. 60%)





Synthetic Paraffinic Kerosine - SPK



Paraffinic **Aromatic**

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Fuel clearance status

- Def Stan 91-91 approved SASOL semi-synthetic Coal-To-Liquid late1990s

- Def Stan 91-91 approved SASOL fully synthetic in Coal-To-Liquid -2008.

- ASTM approved the use of 50% Generic XtL blend via ASTM D7566 – ASTM D1655 Jet A/A-1 - 2009.

- ASTM approval of hydrogenated veg oils/fats (HEFA)– incorporated into ASTM D7566 mid 2011.

More novel feedstock, processes and products under review
Improve efficiency, cost, availability and environmental performance

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Supply Industry Risk Factors

- **Deployment of renewable fuels = risk.**
  - **New specifications, materials and producers.**
  - **Distributed supply chain.**
  - **Fuel is fit for purpose as much from experience and good workmanship as by specification requirements.**
  - **Transport of low volumes in non dedicated systems.**
- **Changes in conventional fuel distribution.**
  - **Increased distribution complexity and change of custody.**

Current refinery and supply system regulation "Fit for Purpose"?

Rolls-Royce alternative fuel programmes

First GTL demo flight

GTL capabilities evaluation
Industry report issued in Q2 08

1 February 2008

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AIRBUS INDUSTRIE

First 2nd gen biofuel demo flight

Biofuels' capabilities evaluation
Industry report issued Q2 09

20 December 2008

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BOEING
AIR NEW ZEALAND

FAA CLEEN programme

In-depth scientific test programme
Industry report will be issued

Current

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BRITISH AIRWAYS

003782 M

Rig and engine testing matrix

		Fuel Description		
	Supplier	Fuel Type and Description		Aromatic content
Baseline blends	Jet A-1/ HEFA (Dynamic fuels) Blends	Jet A-1 (baseline)	Conventional	~16%
		Jet A-1 and SPK1	ASTM 7566 type Blend	8%
		Jet A-1 and SPK1	ASTM 7566 type Blend	4%
		SPK1	ASTM 7566 type SPK	0%
Novel Fully Synthetic fuels	Applied Research Associates	Single Process	Novel Single Process No1	~16%
	Swift Fuels	Blend (2 synthetic streams)	Novel Blend No 1	~20%
	Shell/ Virent	Blend (2 synthetic streams)	Novel Blend No2	~13%
	Byogy	Single Process	Novel Single Process No 2	~9%

- **Range of conventional aromatics.**
  - Challenge the current 8% min.
  - Provides a baseline.
- **Wholly novel products.**
  - Contain no conventional Jet A-1.
  - Meet headline specification.
  - Mix of single process and blends
- **Evaluation:**
  - Specification and detailed speciation.
  - Combustion performance and emissions.
  - Thermal stability.
  - Elastomer compatibility.

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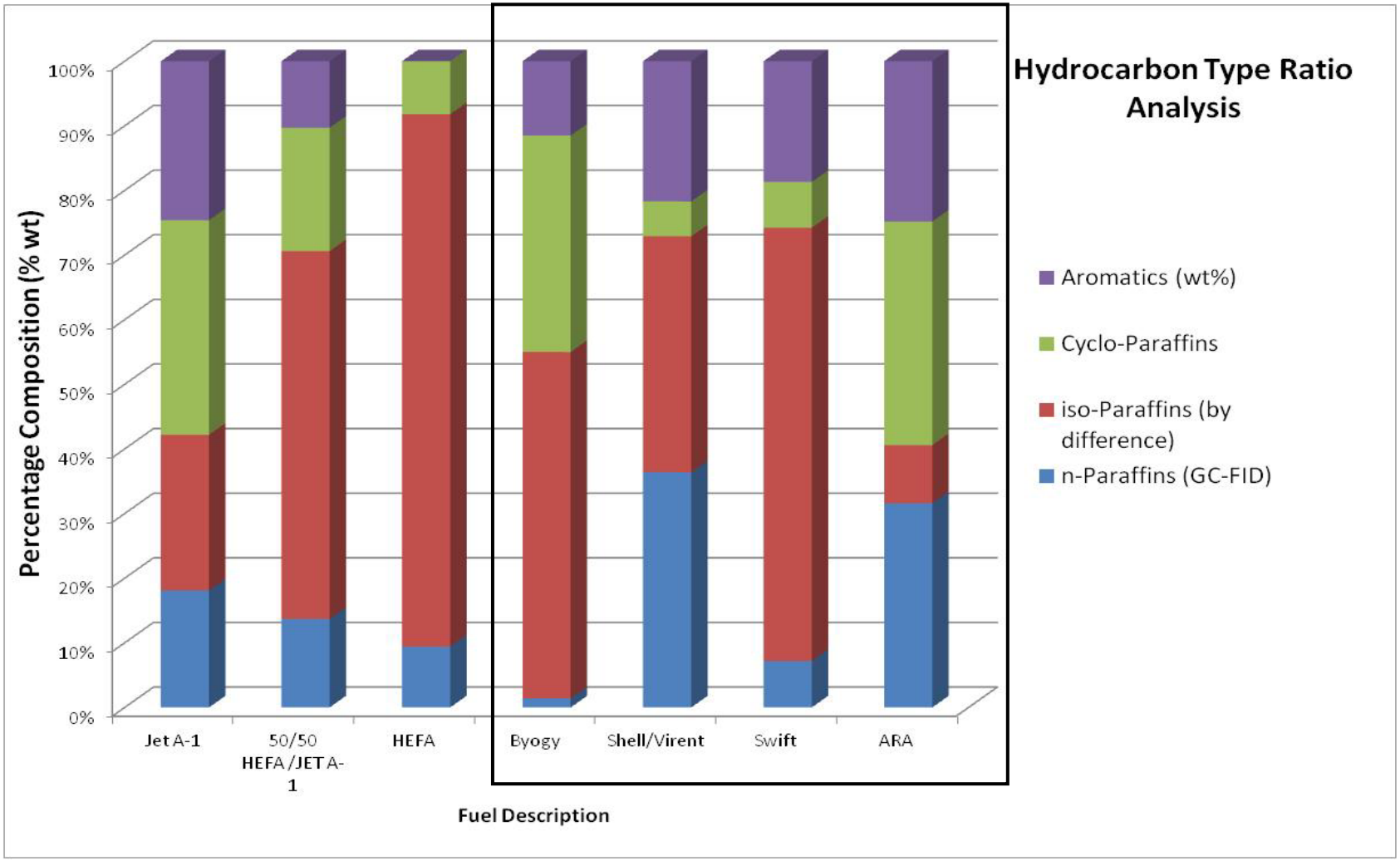
Fuel properties – Hydrocarbons



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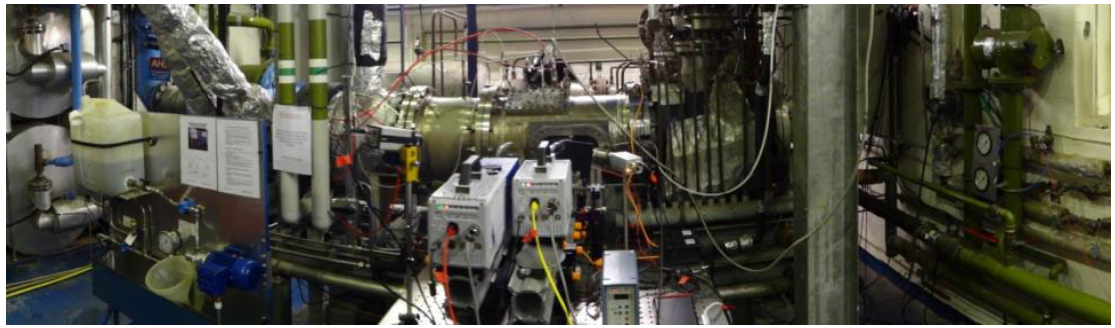
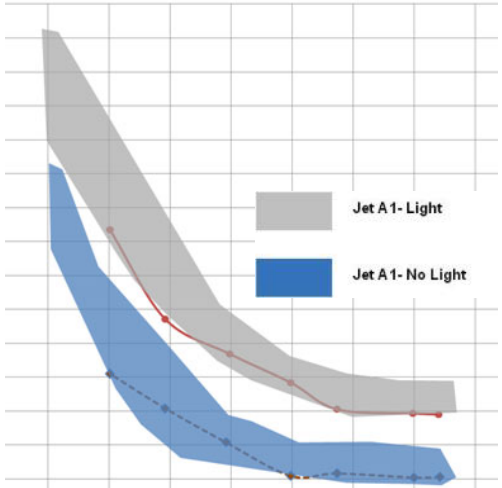
Combustion Operability Test Rig

- Evaluates the high altitude ignition performance of a fuel
- Compare to conventional kerosene



- All Jet A-1/HEFA blends performed within typical Jet A-1 bounds
- The 4 novel fuels showed no significant deterioration relative Jet A-1 ignition performance.



Example plot of data vs Jet A-1

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Combustion and Emissions testing

Small gas turbine: Honeywell APU - ex British Airways 737

- **Comprehensive emissions measurements:**
  - UHC, NOx, NO, CO, CO2
  - SAE smoke number
  - Smoke particulate distribution
- **Range of engine power conditions**
- All fuels showed similar performance and were within the uncertainty of instruments.
- Results confirmed that smoke and particulate emissions are decreased with a reduction in aromatic content

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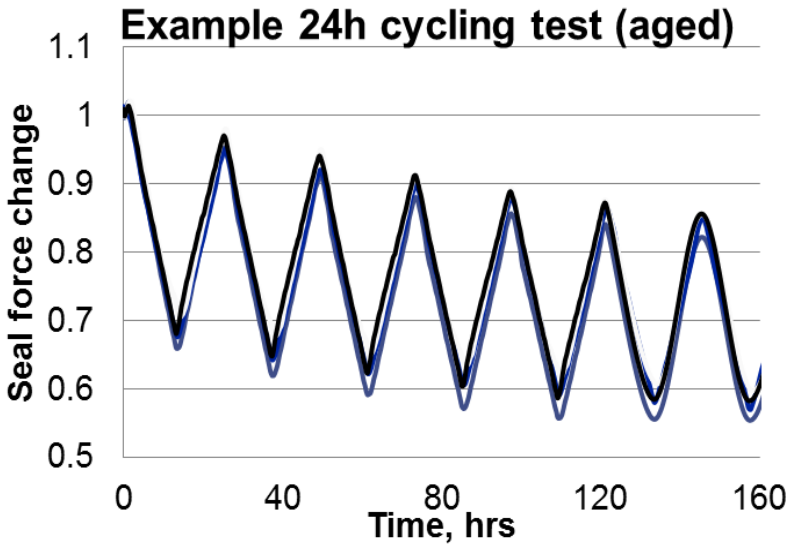
Seal Performance

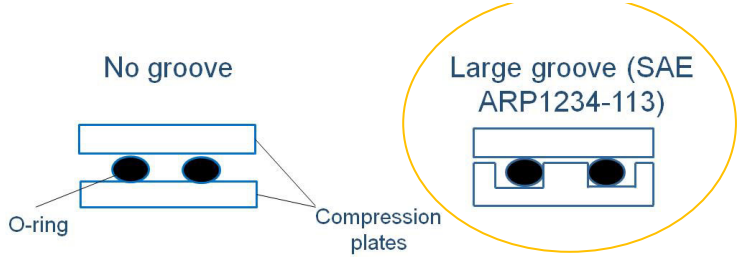
RR/University of Sheffield Proprietary Seal Performance Test.

- **O-ring in realistic engine environment.**
- **Nitrile, fluorocarbon, fluorosilicone seals tested**
- **Real-Time sealing force measurement**
- **Test Regime**
  - Temperature cycling
  - Conventional aromatics (16- 0%)
  - Novel fuels
  - Fuel switching (ongoing)

Range of fuel aromatics versus seal force

Temperature cycle +30C to -40C





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Summary – novel fuel timeline

Achievements Constraints Chances

Timeline	Focus of Industry Activity
Early 1990's to mid 2000's	**Early Approval Process Development** Defining fuel norms and experience Approval of Sasol CtL
2004 - Today	**R & D and Approval Process Definition** Definition & Evaluation Specification Development
Today	**Fuel Approvals** XtL and HRJ – aka SPK, HEFA etc Novel raw materials/processes
2011 - 2050	**Options & Deployment** Capacity and Commercialisation Quality Assurance and Regulation Improved Production Flexibility and Efficiency Sustainability Certification

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END

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