Seminário
Combustíveis Alternativos para a Aviação

29 e 30 de novembro de 2011

Realização

DCA-BR

Organização Brasileira para o Desenvolvimento da Certificação Aeronáutica

Apoio

Associação Brasileira de Aviação Geral
ABAG
www.abag.org.br

abraba
aliança brasileira para biocombustíveis de aviação

ABETAR

CERBIO

EMBRAER

Sindicato Nacional das Empresas Aeroviárias
SNEA

etanol
uma atitude inteligente

AMYRIS

Amyris

The Renewable Carbon Company™

Overview

- Amyris is an integrated renewable products company producing advanced renewable fuels and chemicals:
  - Proprietary technology already delivered first commercial-scale success
  - Use existing sugar/ethanol mills for large volume production
  - Commercial scale renewable products in April 2011
- Founded in 2003 on principle of social responsibility: use our know-how to address biggest health and environmental challenges
- World's leading investors: Kleiner Perkins, Khosla Ventures, TPG

AMYRIS

Our vision: to enable a bio-based economy

Traditional oil source

Oil

+

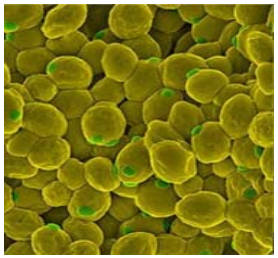
Refinery

= Petroleum products

Fermentation using Amyris' engineered yeast

Biomass Sugars

+



Amyris genetically engineered yeast

= **Hydrocarbon**

Bio-Oils

Hydro-processing

Wide range of products

- Jet fuel
  2020 est: 124 billion gallons
- Diesel
  2020 est: 450 billion gallons
- Chemicals:
  e.g. polymers, lubes and surfactants
- Anti-malaria drug
  non-profit: treat over 200 million people annually

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Enabling Technology
From sugars to hydrocarbons!



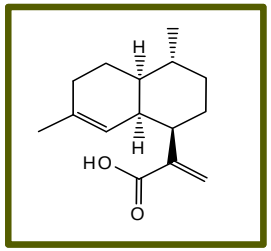

SUGAR SOURCE

Sugar Syrup

YEAST CELL

Isoprenoid Pathway

Artemisinic Acid



p450

CPR

ADS

Farnesene Synthase

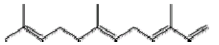
GPPS

IS

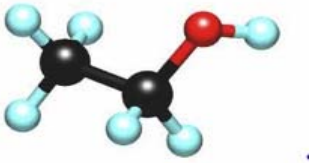
PS

Anti-Malarial Drug

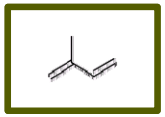
Diesel & Chemical Precursor



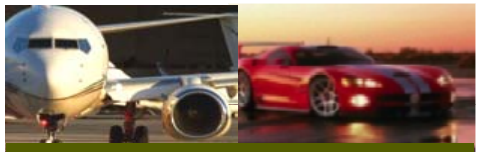
Farnesene



Ethanol



Isoprene



Jet / Gasoline Precursors

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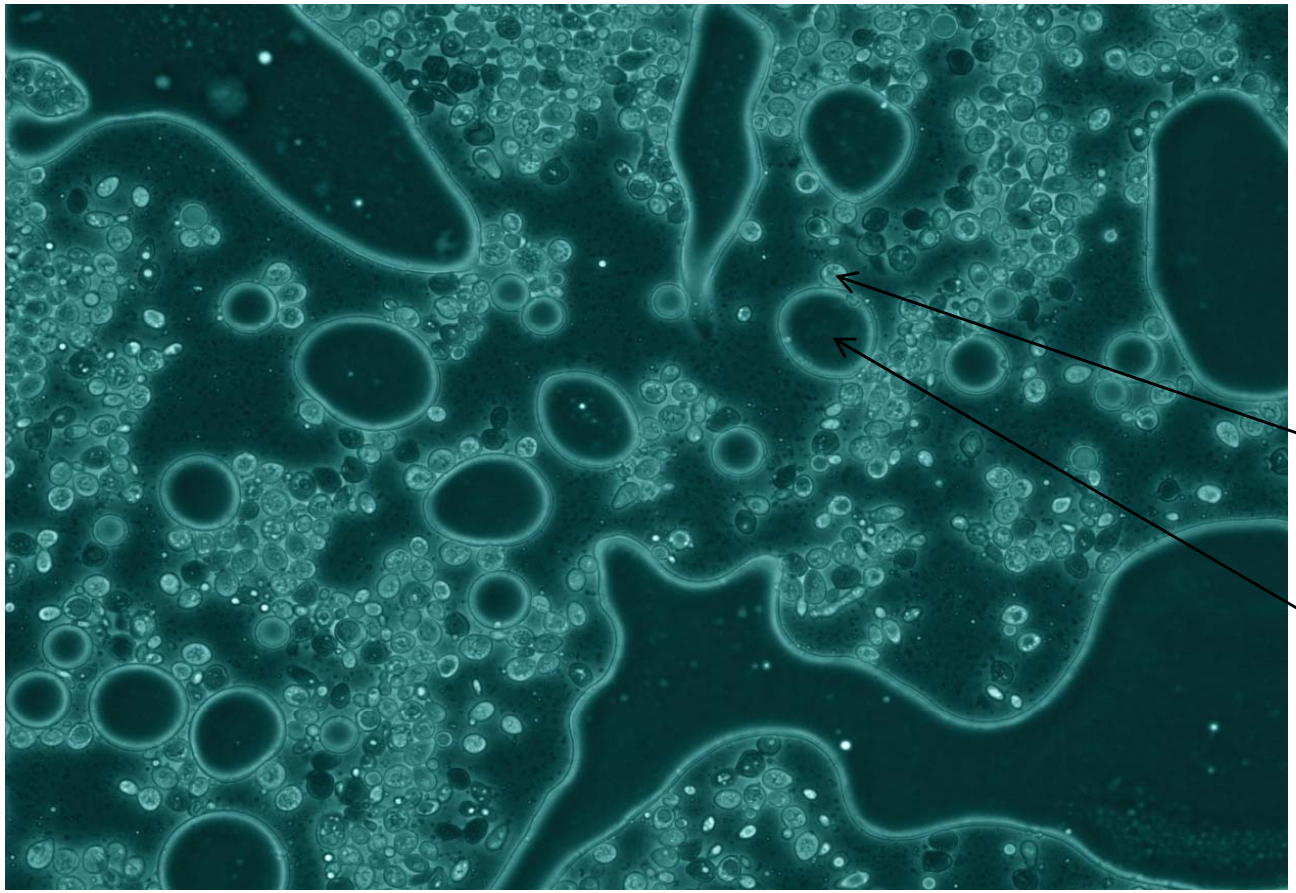
Amyris breakthrough technology

Amyris engineered microbes can convert sugar to Bio-Oils



Phase-contrast micrograph of Amyris engineered microbes producing precursor to Amyris Renewable Diesel

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Amyris No Compromise™ fuels

- **Can produce using diverse sugar feedstocks**
- **Hydrocarbons, not alcohols or esters**
  - Can be used in existing engines with no performance trade-offs
  - Can be blended up to 50%
  - Can be delivered using existing distribution infrastructure
- **Price competitive with petroleum**
- **Superior properties**
  - 80%+ lower greenhouse gas emissions than petroleum
  - No sulfur
  - Lower particulates and NOx
  - Excellent cold flow characteristics and energy density

Amyris diesel fuel (clear) in front; petroleum diesel (yellow) in the back

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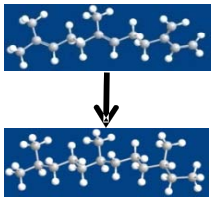
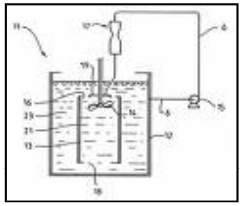
Leverage existing mills for quick scale

Cane Processing/ Electricity Generation → Fermentation → Recovery → Distillation → Dehydration → Hydro-processing

Dehydration
Not required since hydrocarbons separate easily from water

Finishing
Chemical step required to convert intermediate to final product requires hydrogen as raw material





Purification
Energy intensive distillation process not required.
Recovered energy may be utilized in the plant

Simple production process using current mill infrastructure

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Manufacturing timeline for first product

2009

Brazil **R&D center inaugurated in Campinas**

Brazil and US Pilot plant operational

Brazil Demo Facility opened

Secure production in Brazil

- Owned/controlled
- Third parties

2010

Convert Brazil ethanol mills to produce Amyris renewable products

- Basic engineering of commercial plant has been finalized and EPCM CH2MHill has been engaged

Commercialize first product out of demo facility

2011

First large scale production of Amyris renewable products

Continue mill conversion and expansion

2012 - 2013

First commercial production by third party mills

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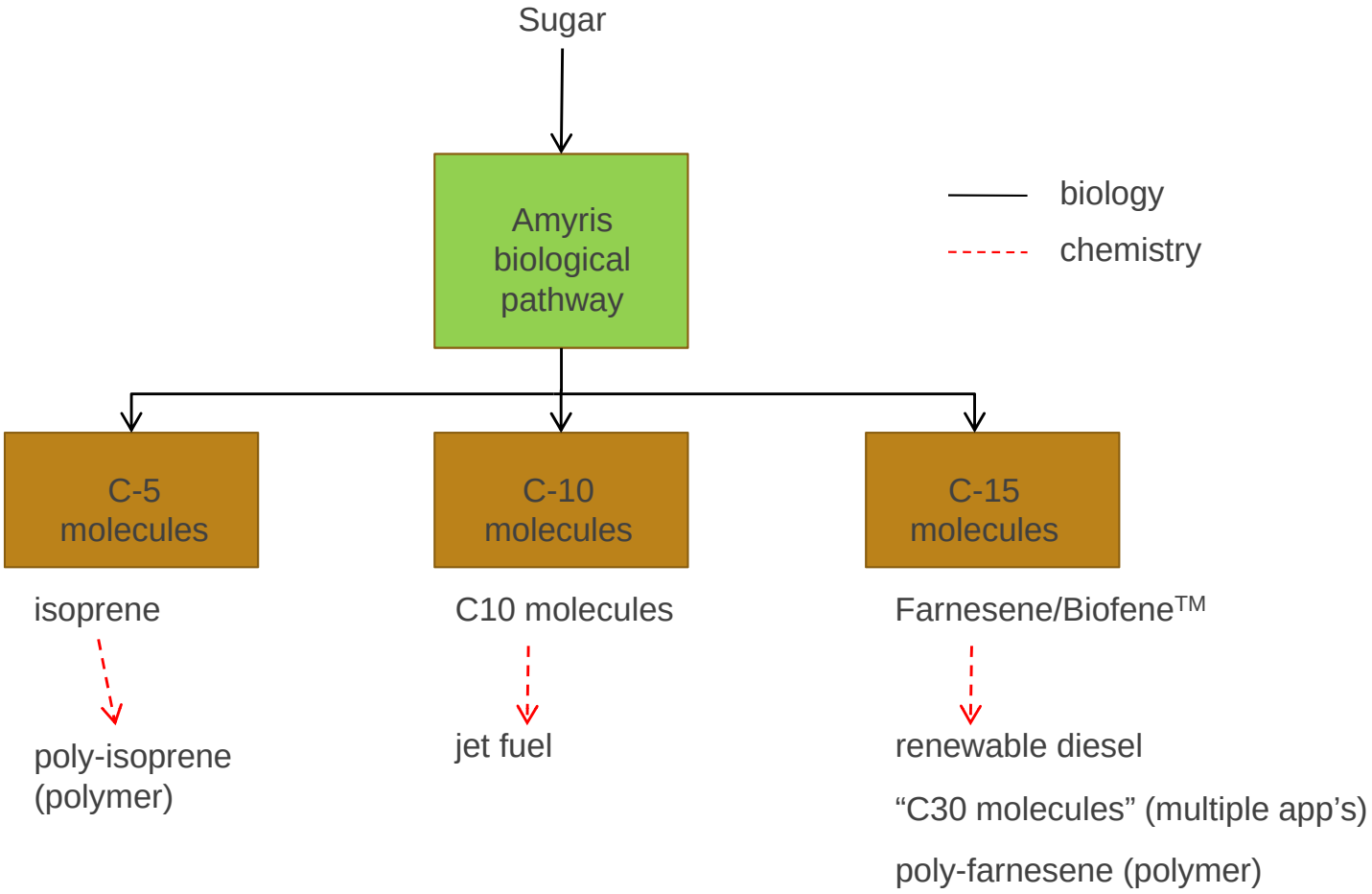
Opportunities from technology platform

Our microbial platform allows us to access over 50,000 isoprenoid molecules biologically. By adding chemistry post bio-production, we can produce multiple products per molecule.



- Unlike chemical processing, a complex series of reactions can occur in a single cell
- Initial focus on the following products
  - C-15: farnesene, renewable diesel
  - C-5: isoprene
  - C-10: jet fuel

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Leading Candidate Fuels

Component	Structure	Formula	Density (kg/m^3)	Product Grades
AMJ-A	Branched cycloparaffin	$C_{10}H_{20}$	801	**AMJ-310** ~16% AMJ-3B; **AMJ-700** • 60% AMJ-310 • 40% AMJ-3C
AMJ-B	Branched aromatic	$C_{10}H_{14}$	820	
AMJ-C	Branched alkane	$C_{15}H_{32}$	774	

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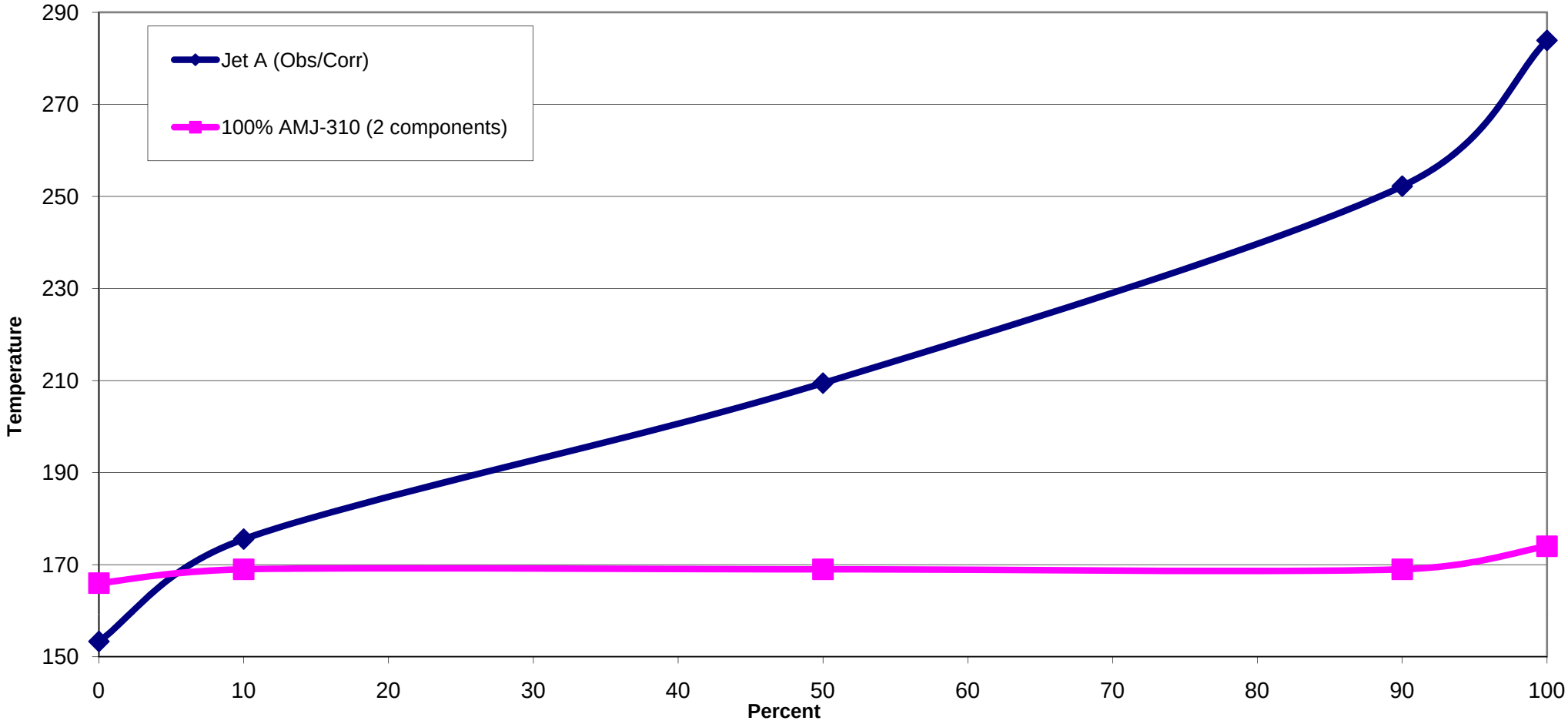
Distillation



Lab: Intertek Caleb Brett (Benecia, CA)

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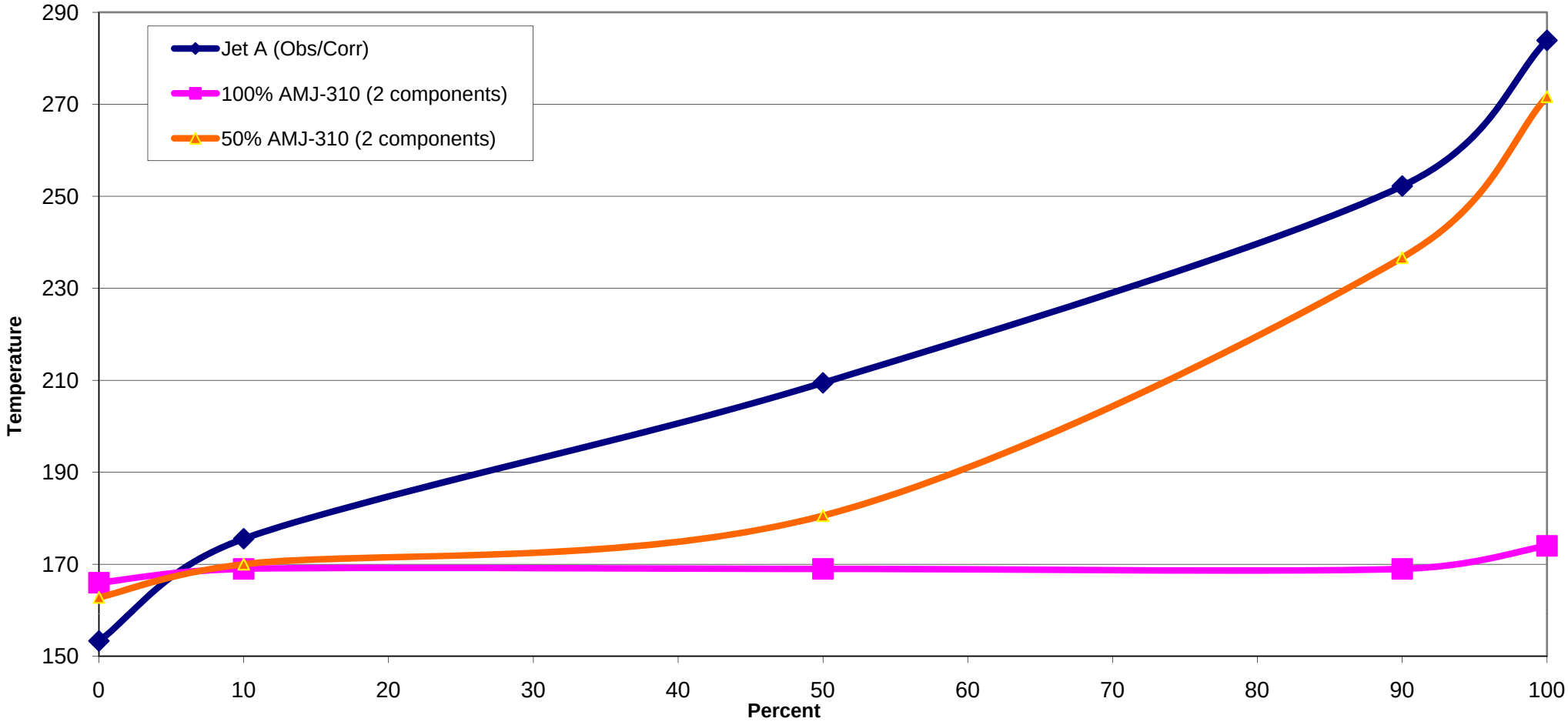
Distillation



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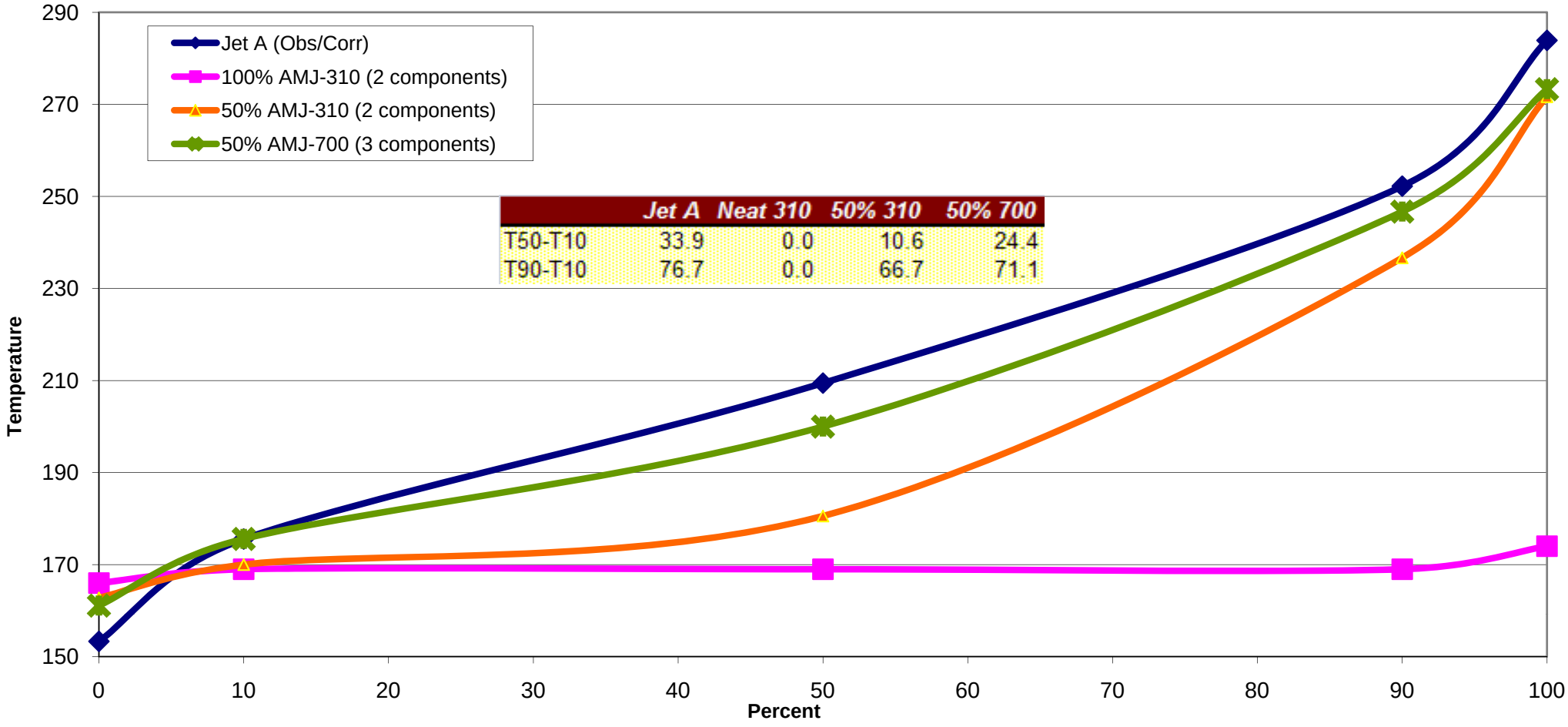
Distillation



	Jet A	Neat 310	50% 310	50% 700
T50-T10	33.9	0.0	10.6	24.4
T90-T10	76.7	0.0	66.7	71.1

Lab: Intertek Caleb Brett (Benecia, CA)

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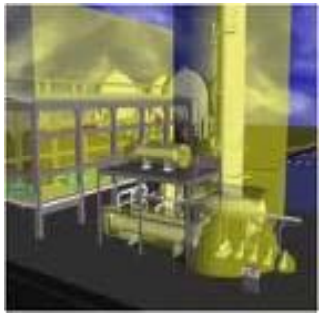
Fuel Production

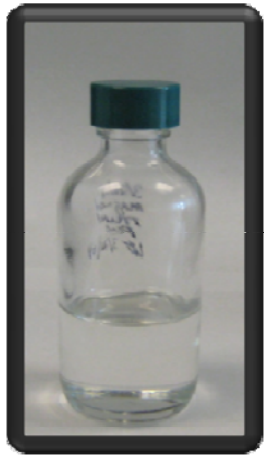
Biomass Sugars

Fermentation

Bio Oil



Hydro-processing



AMJ

Superior Jet Fuel Properties

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Embraer, GE, Azul and Amyris collaboration project

2009 | 2010 | 2011 | 2012

colaboration project announcement to evaluate Amyris renewable jet fuel

Components rig testing

Performance and emissions

Demo flight

Sustainability evaluation

Production process development

Azul Linhas Aéreas Brasileiras

Thank you

Luciana Di Ciero
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Specification Test Results – 1/2

Property	ASTM Test Method	Units	Jet A ASTM D1655 Specification		JP-8 w/50% SPK MIL-DTL-83133F Specification		Jet A	AMJ-310 (vol.% in Jet A) 50
COMPOSITION								
Appearance	D4176-2			C & B		C & B	C & B	C & B
Acidity	D3242	total mg KOH/g	max.	0.10	max.	0.015	0.005	0.013
Aromatics	D1319	vol.%	max.	25	min./max.	8/25	16.9	17.9
Sulfur	D4294	total mass %	max.	0.30	max.	0.30	0.0685	0.0357
Sulfur, mercaptan	D3227	mass %	max.	0.003	max.	0.002	0.0019	0.0009
VOLATILITY								
1. Physical Distillation								
Distillation temperature								
Initial boiling point, temperature	D86	°C					153	163
10 % recovered, temperature	D86	°C	max.	205	min./max.	157/205	176	170
50 % recovered, temperature	D86	°C	max.	report	min./max.	168/229	209	181
90 % recovered, temperature	D86	°C	max.	report	min./max.	183/262	252	237
Final boiling point, temperature	D86	°C	max.	300	max.	300	284	272
Distillation recovery	D86	vol.%					97.6	98.3
Distillation residue	D86	vol.%	max.	1.5	max.	1.5	1.4	1.2
Distillation loss	D86	vol.%	max.	1.5	max.	1.5	1.0	0.5
T50 - T10	D86	°C			min.	15	34	11
T90 - T10	D86	°C			min.	40	77	67
Flash Point	D56	°C	min.	38	min.	38	43	43
Density at 15 °C	D4052	kg/m^3	range	775 - 840	range	775 - 840	811.0	810.5
FLUIDITY								
Freezing point	D2386	°C	max.	-40	max.	-47	-47	-57
Viscosity at -20 °C	D445	mm^2/s	max.	8.0	max.	8.0	5.2	3.3

meets ASTM & MIL specs
Meets ASTM spec, does not meet MIL spec
Meets neither spec

AMYRIS

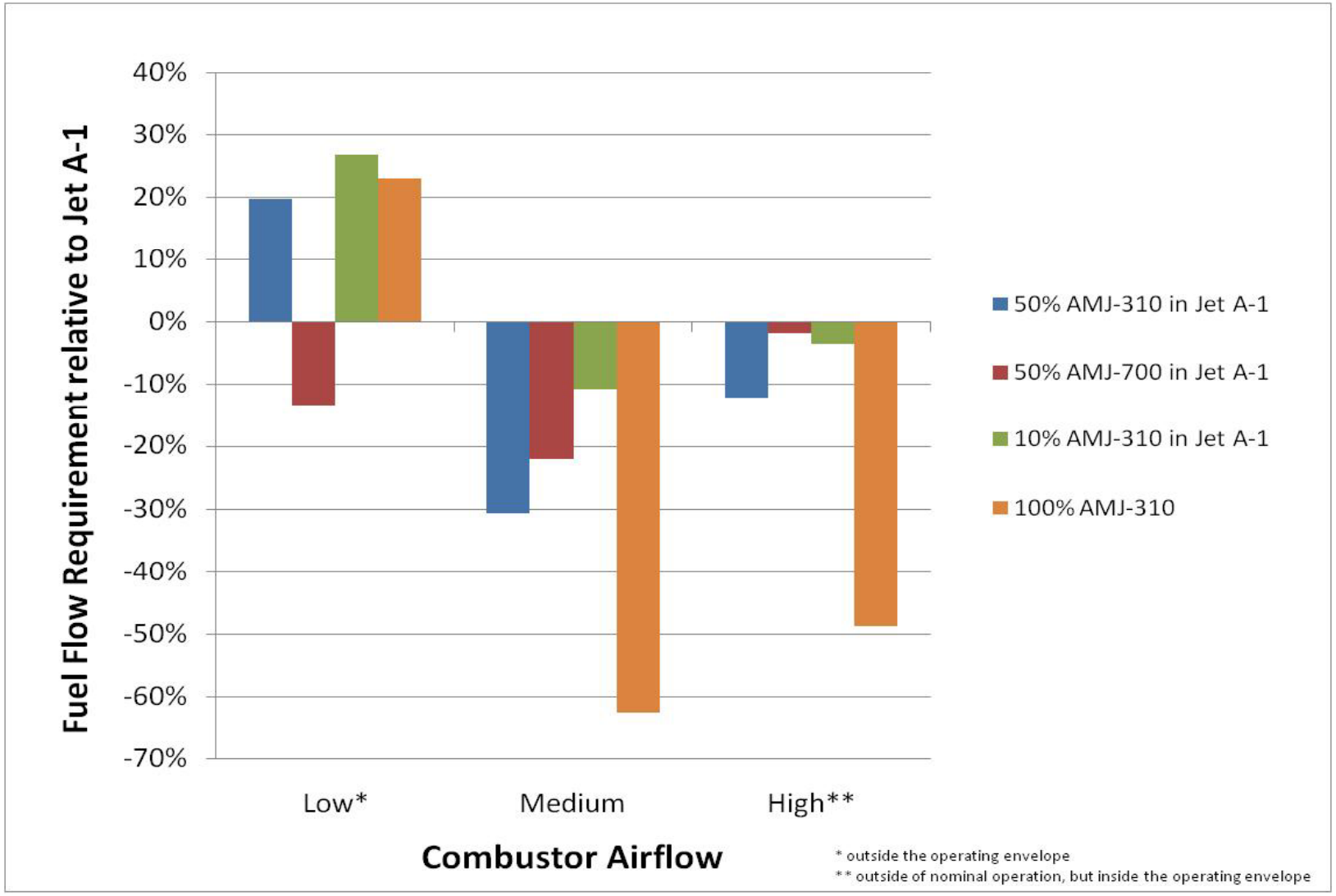
Specification Test Results – 2/2

Property	ASTM Test Method	Units	Jet A ASTM D1655 Specification		JP-8 w/50% SPK MIL-DTL-83133F Specification		Jet A	AMJ-310 (vol.% in Jet A) 50	AMJ-700 (vol.% in Jet A) 50
COMBUSTION									
Net heat of combustion	D3338	MJ/kg	min.	42.8	min.	42.8	43.4	43.1	43.3
Net heat of combustion	D4809	MJ/kg					45.2		42.6
Gross heat of combustion	D4809	MJ/kg						45.4	45.6
Smoke Point	D1322	mm	min.	18	min.	19	21	21	24
Naphthalenes, vol.	D1840	vol.%	max.	3	max.	3	2.46	1.42	1.28
CORROSION									
Copper strip, 2 h at 100 °C	D130			No. 1		No. 1	1A	1B	1B
THERMAL STABILITY									
JFTOT									
Temperature	D3241	°C					260	260	260
Tube deposits less than	D3241			<3		<3	<1	<1	<1
Filter pressure drop / test time (150 min)	D3241	mm Hg/min	max.	25	max.	25	<1	<1	0
Spent fuel	D3241	mL					495	440	510
CONTAMINANTS									
Existent gum	D381	mg/100 mL	max.	7	max.	7	1	2	<1
Water reaction:									
Interface rating (Interface/Separation)	D1094		max.	1b	max.	1b	1b / 2	1b / 2	1b / 2
Change in volume	D1094	mL					0	0	0
Microseparometer (MSEP-A)									
Without electrical conductivity additive	D3948	Rating	min.	85	min.	85	99	98	91
With electical conductivity additive		Rating	min.	70	min.	70			
ADDITIVES									
Electical conductivity	D2624	pS/m					4	2	5

meets ASTM & MIL specs
Meets ASTM spec, does not meet MIL spec
Meets neither spec

AMYRIS

Combustor Rig – Light Off (Cold Start)



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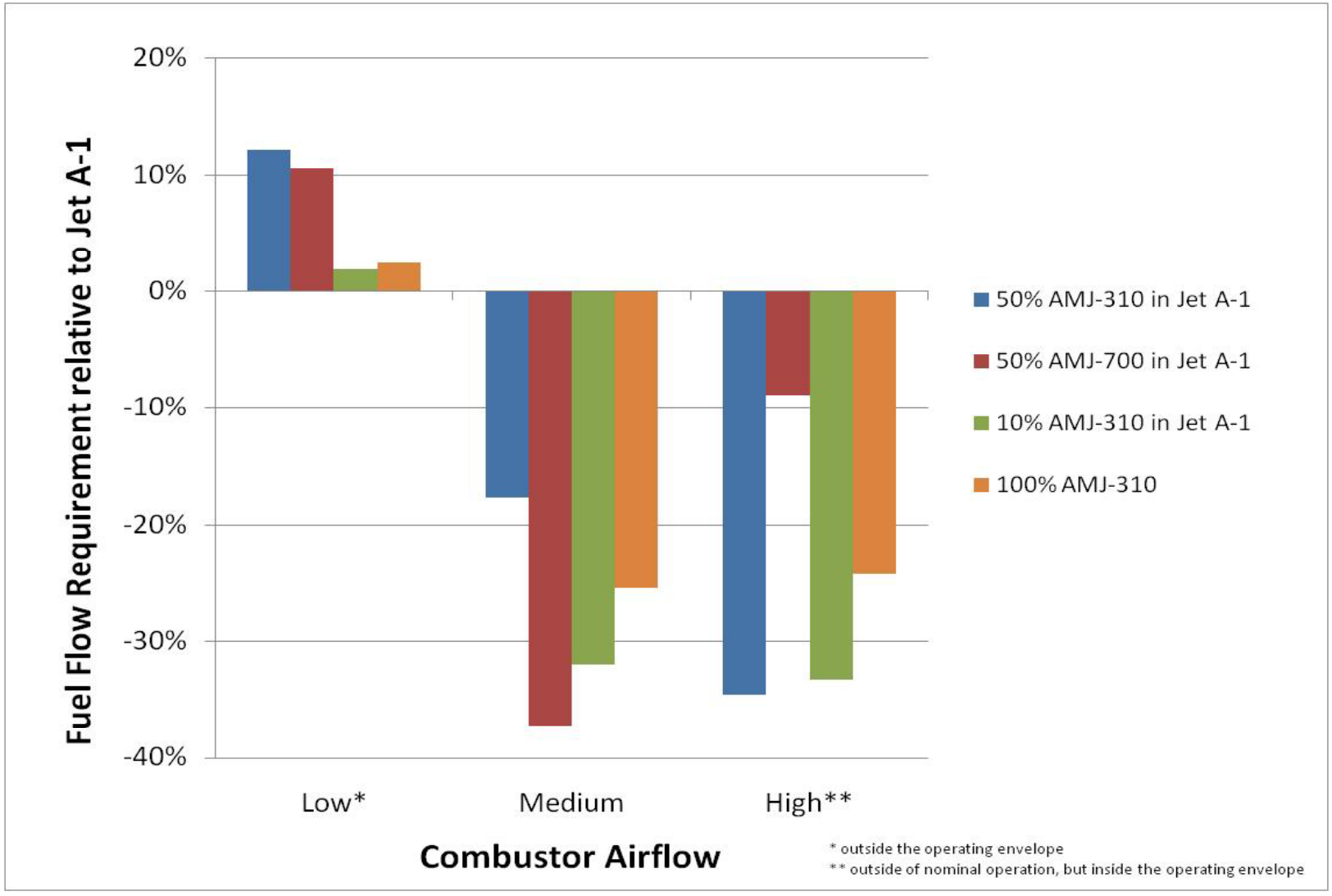
Combustor Rig – Lean Blow Out



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