Transport Canada Civil Aviation Update to the ASCENT Advisory Committee

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Common Objectives

- Key strategic objective for ICAO, Canada and the US
- Long history of close working relationships (15+ with CoEs)
- ICAO's environmental goals include reducing or minimizing:
  - aircraft noise
  - impacts on air quality
  - impacts on the global climate
- R&D is a key component
  - Improved measurement / understanding
  - Clean technology
  - Efficient operations

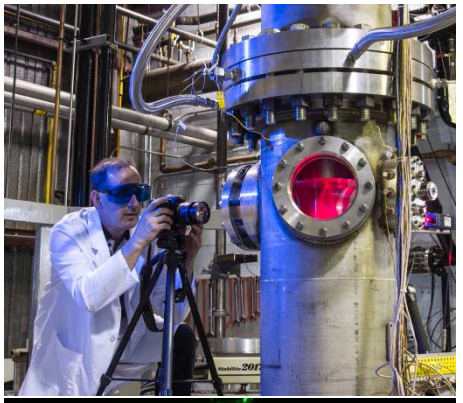
IMPACT CANADA

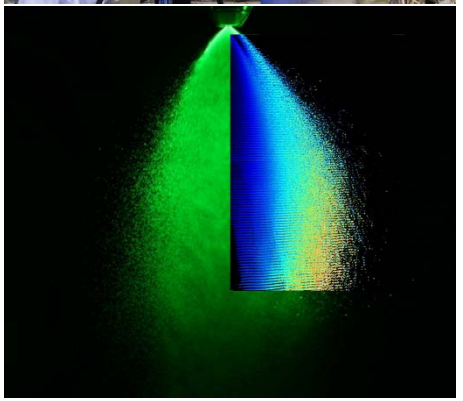
SKY'S THE LIMIT CHALLENGE

- Goal: Made-in-Canada breakthrough in the development of sustainable aviation fuel (SAF) in collaboration with Air Canada, WestJet, and the Green Aviation Research and Development Network (GARDN).
- Four finalists announced May 2019 at CEM/MI Vancouver. Each eligible for $2M project support and have 18 months to produce a 10L SAF sample and detailed scale-up plan.
  - Carbon Engineering (BC) – CO_2 to SAF
  - FORGE (AB) – Waste oils to SAF
  - Enerkem (QC) – Forestry biomass to SAF; municipal solid waste to SAF
  - SAF+ Consortium (QC) – CO_2 to SAF
- Finalists are working with federal labs to develop and test their fuels:
  - CanmetENERGY Devon (AB): Carbon Engineering; FORGE Hydrocarbons
  - CanmetENERGY Ottawa (ON): Enerkem
- $5M grand prize to be awarded in February 2021 to the consortium with the most economical and environmentally sustainable approach for scaling up SAF production in Canada.
- Separate $1M Flight Prize for first to complete cross-Canada (3,500km) commercial flight using made-in-Canada SAF (min. 10% blend) open until January 2021.

National Jet Fuels Combustion Program

- **Motivation:**
  - Reduce time and cost of approving new alternative fuels through fundamental understanding of combustion processes
  - Relate fuel properties / chemistry to combustion figures of merit (FOM) (altitude relight, cold start, and lean-blowout)
- **FAA led initiative comprising industry, academia, federal agencies and allied partners**
- **NRC Canada contributions:**
  - Engine ignition, performance, and emissions testing at high altitude conditions
  - Atomizer spray characterization testing

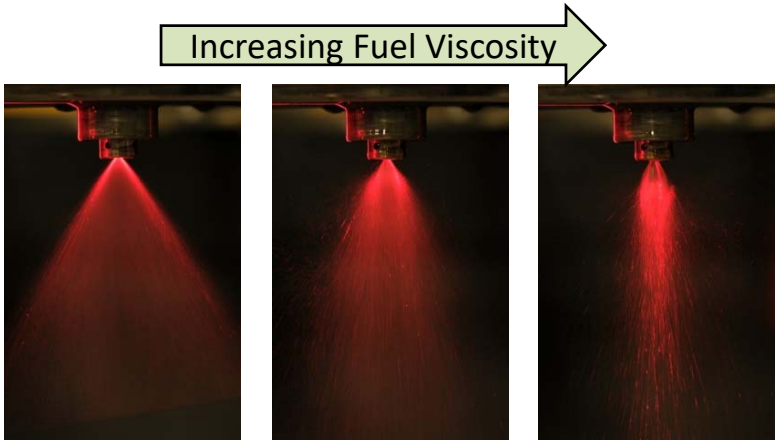




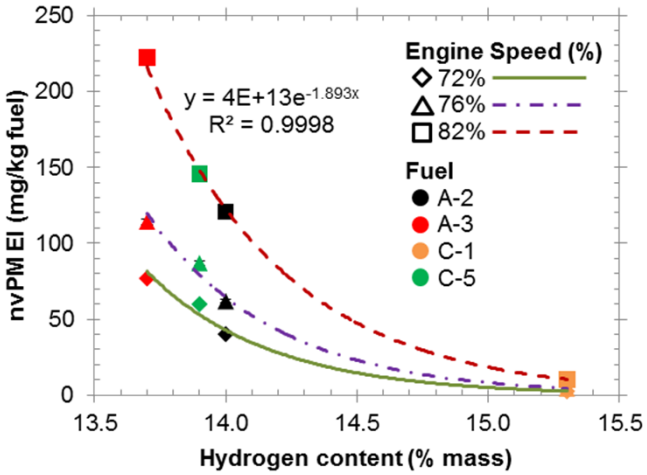
Results

1) **Showed strong dependency on fuel physical properties for altitude ignition on APU sized engine (primary effect on spray/atomization)**
2) **Hydrogen content provided best correlation to nvPM emissions**

TRS-18 Engine Fuel Nozzle Spray



TRS-18 Engine nvPM Emissions



Publications

1) Chan, T.W., Canteenwalla, P., Chishty, W.A., “Characterization of Fuel Composition and Altitude Impact on Gaseous and Particle Emissions From a Turbojet Engine”, ASME Turbo Expo 2017, GT2017-63131.
2) Canteenwalla, P., Chishty, W.A., “Investigation of Engine Performance at Altitude Using Selected Alternative Fuels for the National Jet Fuels Combustion Program”, AIAA SciTech 2017, AIAA-2017-0150.
3) Canteenwalla, P., Corber, A., Chishty, W.A., “Correlation of Alternative Jet Fuel Physical Properties to Engine Ignition at Altitude Conditions”, AIAA SciTech 2018, AIAA-2018-0137.
4) Corber, A., Rizk, N., Chishty, W.A., “Experimental and Analytical Characterization of Alternative Aviation Fuel Sprays Under Realistic Operating Conditions”, J. Eng. Gas Turbines Power, GTP-18-1568, 2018.

Emissions measurements in the upper troposphere / lower stratosphere (UTLS), and the usage of bio-derived jet fuel, recent projects:

- NRC at NASA ACCESS II, 50%
- GARDN project CAAFCER with U of Alberta (J Olfert) and Air Canada
- CAAFCEB with ECCC/TC, 92% ATJ SPK
- CAAFCOMR, 100% ATJ SPK, no aromatics

Objectives: UTLS cruise measurements of emitted particulates and contrail generation

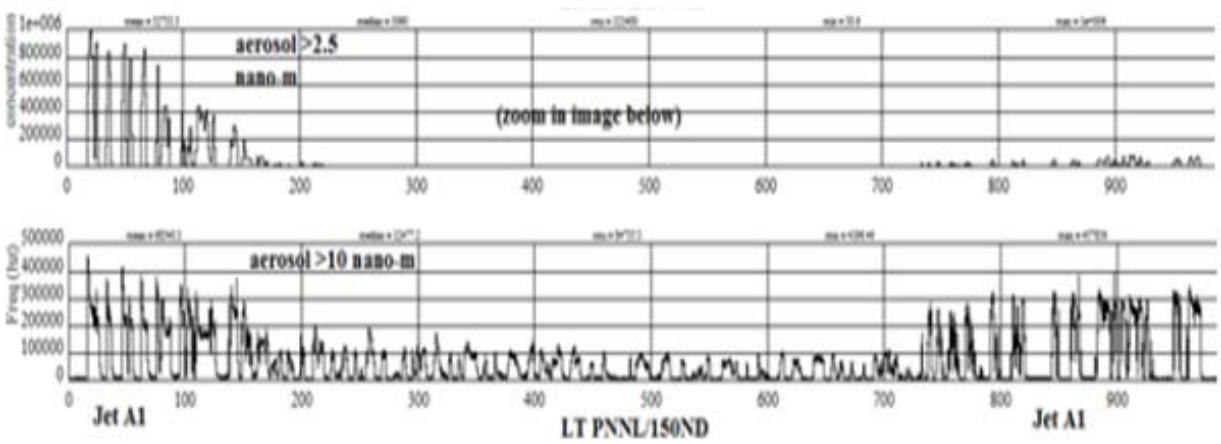
CAAFCEB – PM summary, 92% biofuel

Particulate matter (PM & nvPM, in high altitude M0.8 cruise (constancy of altitude, engine operating condition, fuel between flights):

- JetA1
  - 7.5% ultrafines (CPC, >2.5 nano-m) were non-volatile (nv), with 3x PM between 2.5-10 nano-m – such as sulphates.
- A-3 JP-5
  - nvPM higher than JetA1 (largely, soot)
  - 12% of CPC were nv (higher % than JetA1 likely due to lower sulphur)
- 92% LT PNNL / 8% 150 ND
  - large reduction in PM (time-trace)
    - 80% reduction in nv (soot)
    - 91% reduction in ultrafines
    - Less volatiles (nvPM was 19%)

CAAFCEB mean values of EIn for aerosols, ultra-fines, non-volatiles

Fuel	Mean values of EIn for			For each fuel:
	CN	CPC	CPCnv	CPCnv/CPC
JetA1	1.1286e+16	4.6236e+16	3.4705e+15	0.0751
JP5	1.3311e+16	5.6662e+16	6.8873e+15	0.1216
LT PNNL	1.9884e+15	4.1636e+15	6.7268e+14	0.1616
Ratio LT PNNL to JetA1	0.1762	0.0901	0.1938	



WG-22: Civil Aviation Alternate Fuel Contrail and Emissions Research (CAAFCER)

- HEFA biojet is sourced from Canadian produced feedstock, and delivered blended at 43%, tested and tankered at Pearson International Airport.
- Comparing the characteristics of persistent contrails formed from petroleum jet fuel and biofuel through a series of 5 commercial biofuel flights. NRC T-33 takes off from Ottawa and vectored by Air Traffic Control to AC flights from Toronto to Montreal.
- The project advanced the state of science of contrail research and the Canadian contribution in the field.
- AJF has a higher hydrogen and lower sulfur content, therefore leading to reduced size of contrail ice particles. At 43% blend, the size of the contrail ice particles was 10% smaller than 100% JetA1.

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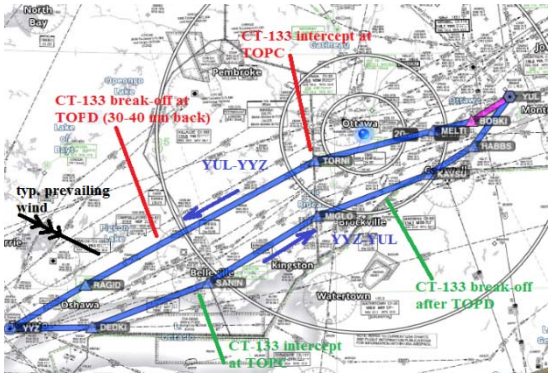
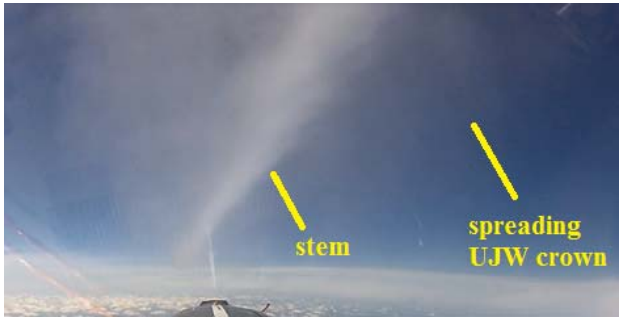
Civil Aviation Alternate Fuel Contrail and Emissions Research (CAAFCER)

- Air Canada A320/321 on 43% HEFA blend, YUL->YYZ, plus
- Jet A1 A320/A321/B763 YYZ->YUL
  - Both measured back-back by NRC CT-133 research jet
- HEFA supplied by Alt-Air, LAX
- Blended by Air Canada and SkyNRG at Montreal
- U of Alberta, aerosol, nvPM analysis
- Boeing, technical advice & oversight
- DND QETE analysis of tank fuel samples





NEC-21: Assessment of likely Technology Maturation pathways used to produce biojet from forest residues (The ATM Project)

▪3 biocrudes were sourced from 3 different processes (fast pyrolysis, catalytic pyrolysis, hydrothermal liquefaction) and two hydrotreatment methods used for a total of 6 pathways analyzed

- All successfully used to produce a significant volume of biojet fuel with a high level of compliance with general standards. Significant jet fraction was produced in all the pathways from all three biocrudes and all upgrading methods.
- **Significant emission reductions were possible with many of the pathways.**

▪Evaluation included analysis of fuel products, life cycle assessment (LCA) and techno-economic assessment (TEA)

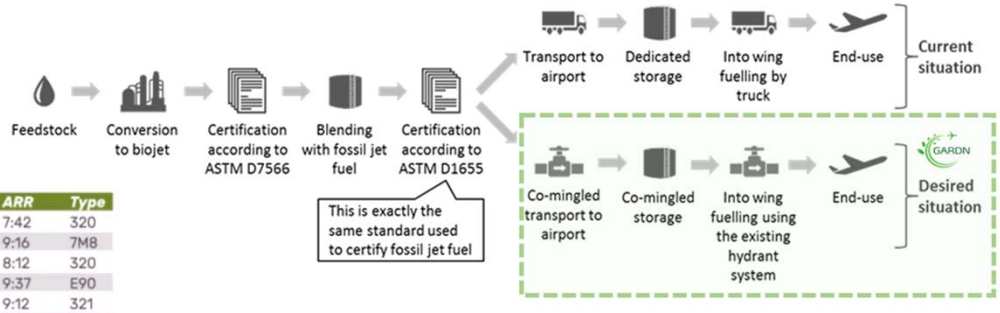
- **The greatest sensitivities to the net present value were biocrude CAPEX, feedstock cost and hydrogen cost**.
- The various pathways showed a minimum fuel selling price between CAD 1,742 - CAD 3,926 per metric ton of fuel for the different pathways.

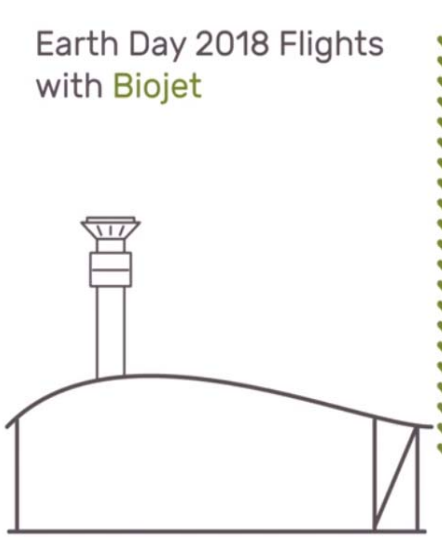
-The pathways evaluated are still being optimised and do not present a static state of technology and therefore improvements are needed to take it further.

- Flow sheets were developed for a 200 bbl/d technology demonstration facility which would produce enough jet fuel for up to 10 medium-haul flights per day as a 10% blend.
- **Further optimization of the HTL pathway with dedicated hydrotreating, based on a demonstration facility of 200 bbl/day, could deliver emission reductions of 71%.**

WG-21: Canada's Biojet Supply Chain Initiative: Enabling 2020 Carbon Neutral Growth

This project completed the first-ever introduction of SAF into the hydrant of Canada's largest airport (Pearson) in support of Earth Day 2018 and supplied 260K litres of biofuel to 22 domestic flights with a 30% blend.





Flight	DEP	ARR	DATE 2018	DEP	ARR	Type
AC480	YYZ	YUL	SU 22 APR	6:30	7:42	320
AC133	YYZ	YYC	SU 22 APR	7:00	9:16	7M8
AC400	YYZ	YUL	SU 22 APR	7:00	8:12	320
AC259	YYZ	YWG	SU 22 APR	8:00	9:37	E90
AC402	YYZ	YUL	SU 22 APR	8:00	9:12	321
AC137	YYZ	YYC	SU 22 APR	8:10	10:25	7M8
AC442	YYZ	YOW	SU 22 APR	8:10	9:10	E90
AC404	YYZ	YUL	SU 22 APR	9:00	10:12	320
AC139	YYZ	YYC	SU 22 APR	10:00	12:16	7M8
AC406	YYZ	YUL	SU 22 APR	10:00	11:12	320
AC261	YYZ	YWG	SU 22 APR	10:05	11:37	319
AC446	YYZ	YOW	SU 22 APR	10:10	11:10	E90
AC107	YYZ	YVR	SU 22 APR	10:15	12:20	320
AC408	YYZ	YUL	SU 22 APR	11:00	12:12	320
AC410	YYZ	YUL	SU 22 APR	12:00	13:12	320
AC450	YYZ	YOW	SU 22 APR	12:10	13:10	E90
AC143	YYZ	YYC	SU 22 APR	12:45	15:01	7M8
AC111	YYZ	YVR	SU 22 APR	12:45	14:50	319
AC263	YYZ	YWG	SU 22 APR	12:55	14:32	E90
AC452	YYZ	YOW	SU 22 APR	13:10	14:10	320
AC145	YYZ	YYC	SU 22 APR	14:40	16:56	7M8

Provided analysis, reporting and dissemination of all CBSCI project knowledge, including detailed operational reports, via the online platform to further validate the biojet supply chain and the emerging biojet opportunity in Canada.

Generated hands-on operational experience and disseminating it for sector advancement via the project's website: www.cbsci.ca

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CBSCI Earth Day Blending 2018

BioPortYVR

An Action-Oriented Feasibility Study

Rationale

- BioPortYVR has the potential to set the standard in sustainability by establishing an integrated, scalable and economical SAF supply chain.
- Vancouver International Airport (YVR) is committed to sustainability and reducing emissions through Sustainable Aviation Fuel (SAF).

Objectives

- Following the results of the study, bring all levels of government together and build the necessary public-private partnerships for a successful BioPortYVR deployment.
- BioPortYVR will pave the way for establishing BioPorts and SAF distribution supply chains at other airports in Canada.

Other projects and initiatives

Advisory services (in collaboration with RSB*)

- GARDN will represent RSB* in North America by providing à la carte services for sustainable certifications to the SAF industry.
- The first beneficiaries to whom the services will be offered are the participants of the NRCan Challenge (either a finalist or not).

SAF Talk Conference 2020

- Save the date: May 12-13 2020
- This conference will bring together all stakeholders of the SAF supply chains from feedstock producers to end user, government and policy experts, airports and airlines, etc. The program is being drafted.
- The conference is organized by GARDN and a section of the content will be dedicated to CAAFI with whom a partnership (MoU) will be signed.

SAF Community and NEVIA platforms.

- SAF Community is an online social network aiming at bringing together SAF stakeholders (Canadian or foreign) to facilitate communication and collaboration through the people directory, forums, news feed and events, etc. An organic growth strategy is being developed.
- NEVIA Platform is aiming to perform the same objective for the green aviation community first, and then expand to the aerospace industry. The platform is being prepared for beta testing.

* Roundtable on Sustainable Biomaterials, world's leading sustainable certification body

Opportunities for Expanded Collaborations

- ASCENT
- CAAFI
- U.S. Dept of Energy and Natural Resources Canada, and other departments at the Federal and State / Provincial levels
- Operators, Airports, Air Navigation Service Providers, and Manufacturers *(including electric aircraft)*

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