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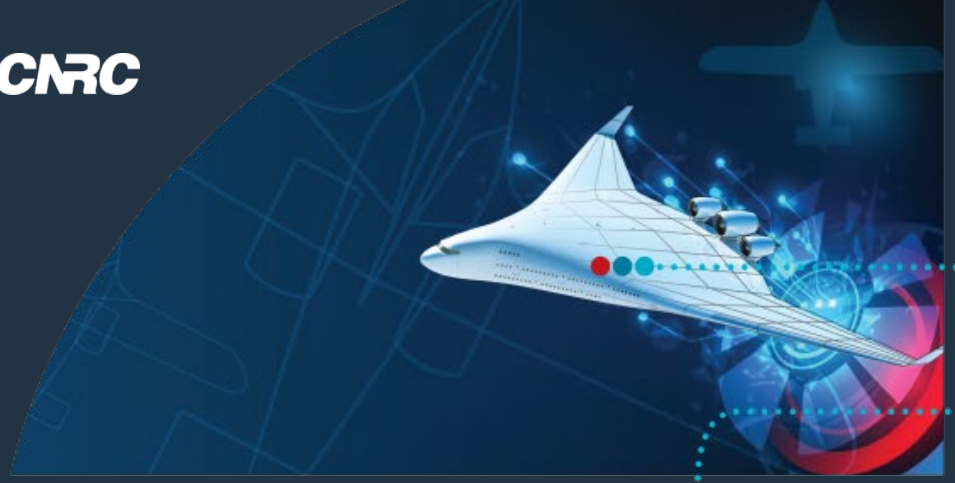
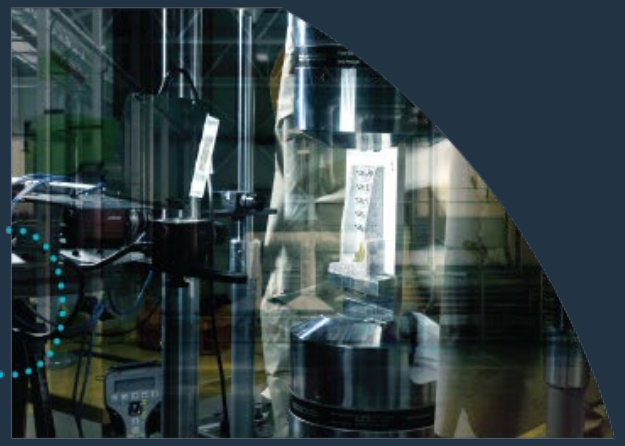




DAIR and NRC:
Webinar on Green Aviation

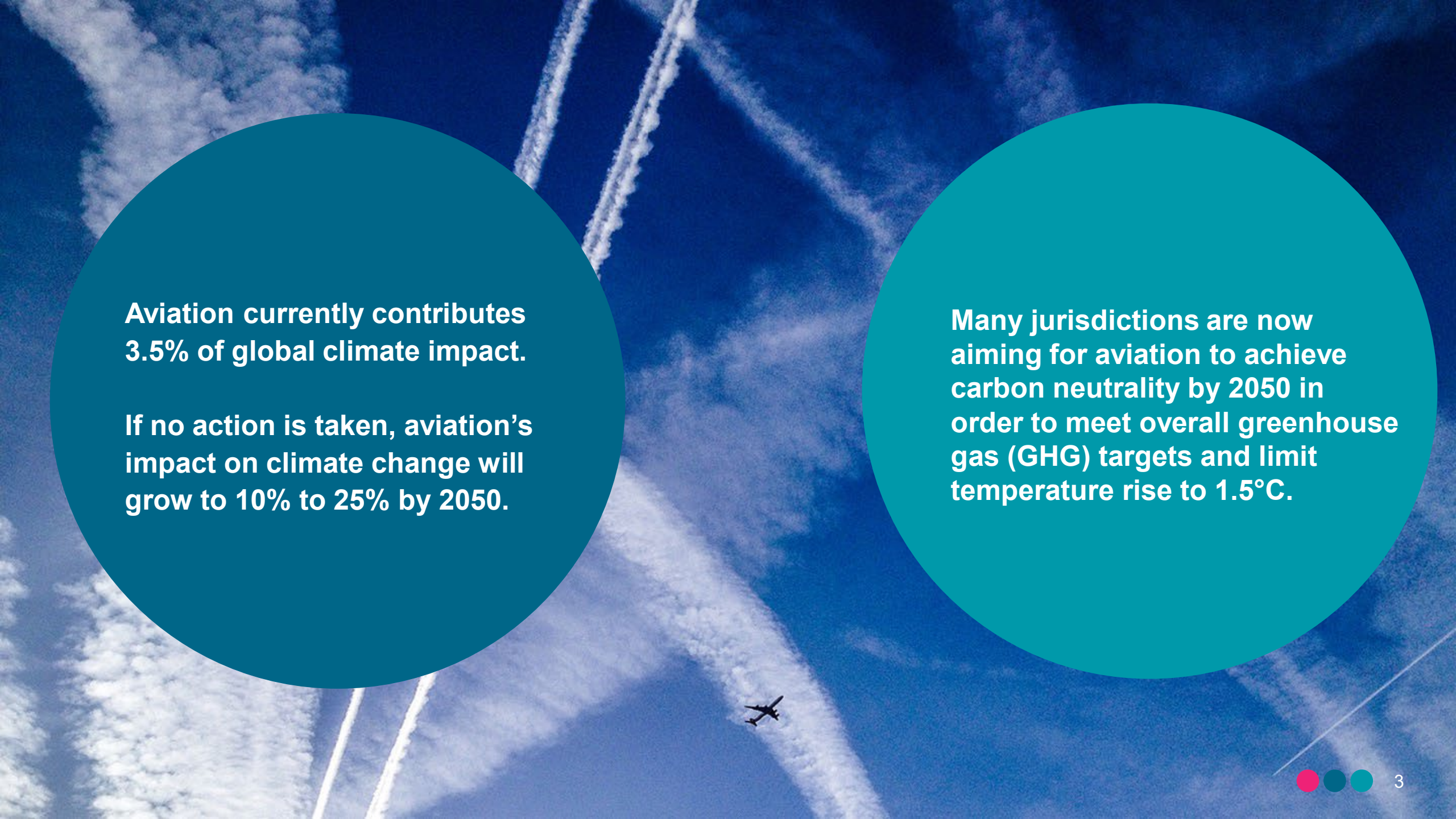
NRC Aerospace Research Centre

DAIR
September 20, 2022

National Research Council Canada
Conseil national de recherches Canada

Canada

THE RATIONALE



Aviation currently contributes 3.5% of global climate impact.

If no action is taken, aviation's impact on climate change will grow to 10% to 25% by 2050.

Many jurisdictions are now aiming for aviation to achieve carbon neutrality by 2050 in order to meet overall greenhouse gas (GHG) targets and limit temperature rise to 1.5°C.

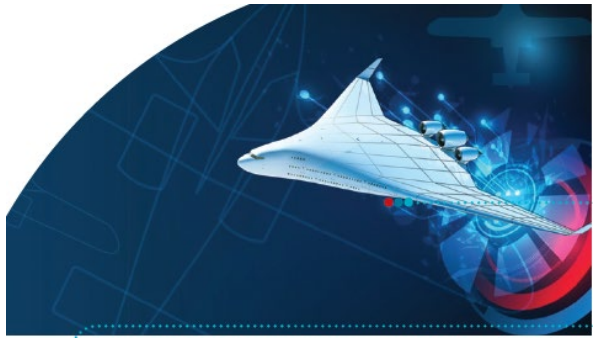
Greening Aviation – The Options

Aircraft Lifecycle Analysis

- *The "use" stage of an aircraft's life accounts for >99% of its lifecycle emissions.*

Better Operations

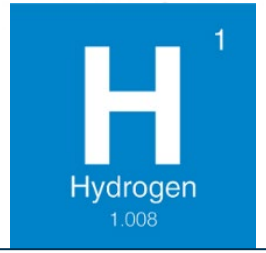
Advanced Airplanes



Clean Energy

Sustainable Aviation Fuels

Electrification

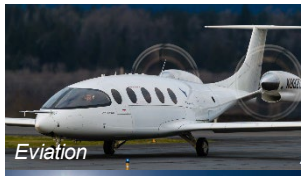


Hydrogen

Time Frame:	Near-term	Near-term	Mid to Long-term	Near-term	Mid to Long-term
Impact (GHG reduction):	<10%	<10%	<30%	30-60%	75-100%

One Size Doesn't Fit All


Jaunt



		2022	2025	2030	2035	2040	2045	2050	
1MW >	**Commuter** 9-50 seats < 60-minute flights < 1% of industry CO^2	SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	27% of CO^2 emissions
	Regional 50-100 seats 30–90-minute flights 3% of industry CO^2	SAF	SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	
	Short—Haul 100-150 seats 45–120-minute flights 43% of industry CO^2	SAF	SAF	SAF	SAF potentially some hydrogen	Hydrogen and/of SAF	Hydrogen and/of SAF	Hydrogen and/of SAF	
100 MW <	**Medium-Haul** 100-250 seats 60–150-minute flights 43% of industry CO^2	SAF	SAF	SAF	SAF	SAF	SAF	SAF potentially some hydrogen	73% of CO^2 emissions
	Long-Haul 250+ seats 150+ minute flights 30% of industry CO^2	SAF	SAF	SAF	SAF	SAF	SAF	SAF	

*Assumes that electrical grid and/or hydrogen production are "green".
Source: Air Transport Action Group's (ATAG) Waypoint 2050 – A vision of net-zero aviation by mid-century

	State of the Art		Need for Larger Aircraft
BATTERY	~170 Wh/kg	x4	>700 Wh/kg
MOTORS	~2.5 MW & 5 kW/kg	x2	>5 MW & 13 kW/kg with >98% efficiency
SAF	~$5/L	÷5	~$1/L
NOVEL AIRCRAFT ARCHITECTURES	Lab-scale demo		Flight demonstrators
H2 STORAGE EFFICIENCY (mass of fuel / total mass of tank + fuel)	~14.5% (liquid)	x2	>35%

Several recent examples on feasibility of battery electric / hydrogen flight

2018 — 2019 — 2020 …and many more

Serial Hybrid
1x Diesel Generator +
2x All-electric (battery)

Diamond Aircraft

Hybrid
1x ICE +
All-electric (battery)

Ampaire

All-electric (battery)

Harbour Air

All-electric (Hydrogen + battery)

ZeroAvia

Canadian Context: Future examples

CAE

Piper Archer - All-electric

Battery powered (0.15 MW)

P&WC / DHC

Dash 8-100 -Turboprop Hybrid Electric

Re-engine one side (1 MW)

Bombardier

EcoJet - Conventional Turbofans (SAF)

Lifting Fuselage with High-Aspect Ratio Wing

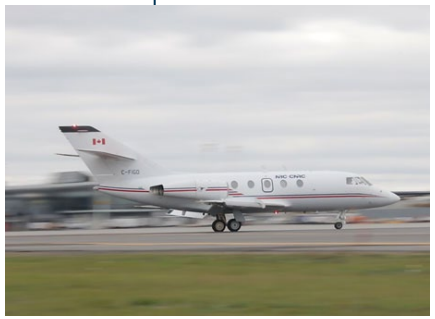
Projects done with support from Governments (federal + provincial)

Similar international efforts underway.

NRC AEROSPACE
THE PAST AND THE FUTURE

Sustainable Aviation at NRC – The past decade

2012



World's first flight on 100% Sustainable Aviation Fuel (SAF)

2014

Participation in NASA ACCESS II SAF contrail flights (multiple NRC campaigns followed)

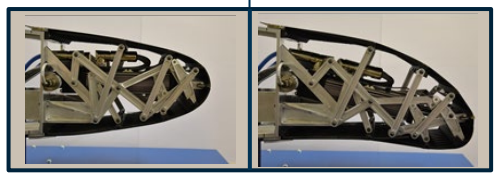
2015

Collaboration started with National Jet Fuel Combustion Program (NJFCP) for faster approval of SAF

2018

Low-pressure hydrogen combustion experiments

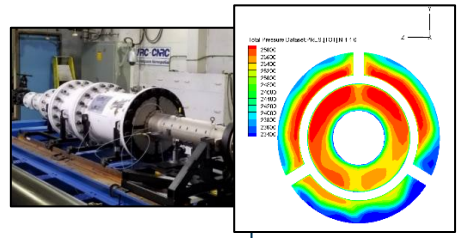
2019



Morphing wing technology developed

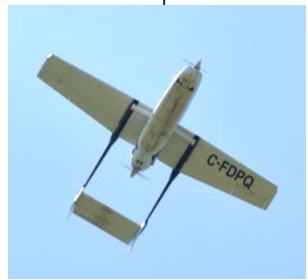
2020

Boundary Layer Ingestion scaled experiments



2021

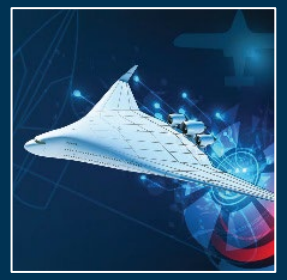
Hybrid-Electric Research Outfit (HERO) Commissioned



Hybrid Electric Aircraft Testbed (HEAT) Developed

Leap forward

NRC Low Emission Aviation Program (LEAP) Focus Areas

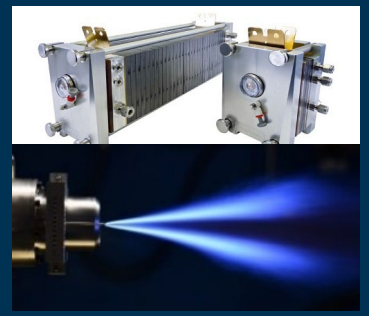


Master Project 1: Aircraft Technology Integration

- Develop, evaluate, and integrate low emission technologies safely into aviation applications.

Master Project 2: Electrical Systems

- Advancement of technologies of the electric engine to improve its performance and reliability as well as methods for integration in the aircraft, testing and certification.



Master Project 3: Hydrogen Technologies

- Hydrogen storage solutions.
- Fuel cell systems for aircraft propulsion and power.
- H_2 safety strategies and regulatory compliance for airborne applications.
- Hydrogen and low carbon fuels for combustion in aircraft gas turbines.

Master Project 4: Battery Safety

- Advancement of safety and suitability of battery technologies to enable aircraft electrification.

Will take a multi-sectoral approach with all stakeholders involved (fuel/electricity producers, airports, regulators, OEMs, etc.).

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Thank You

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