FOR A SUSTAINABLE CANADIAN AVIATION
# Table of Content

About GARDN 4  
About BL-NCE 4  
Message from the Chairman 5  
Message from the Executive Director 6

**OBJECTIVES**

The environmental objectives of the industry 7  
A quick overview of GARDN 8

**SUCCESS STORIES**

Facts and figures of the year 9  
GARDN II Environmental Assessment Report 10

**ACTIONS**

The White Paper, mandated by ECCC 11  
SAF Community 12  
The Sky’s the Limit Challenge, the next step 13  
Networking & visibility 14-15

**PORTFOLIO**

Summary–19 projects 17  
GARDN II research portfolio 18-24

**ADMINISTRATION**

Thank you Sylvain Cofsky 25  
Board of Directors 26  
Executive Committee 26  
CEO Performance Evaluation Committee 26  
Scientific Committee 27  
Integration Committee 27  
Finance and Audit Committee 27  
Nomination Committee 27

**NETWORK**

Industries 28  
Universities, colleges and research organizations 29  
Associations and governmental organizations 29
The Green Aviation Research and Development Network (GARDN) is a non-profit organization created in 2009 with funding from the Business-Led Network of Centres of Excellence (BL-NCE) of the federal government and Canadian aerospace industry.

GARDN’s mission is to help support and increase Canada’s competitiveness in the aerospace industry, by reducing the environmental footprint of the next generation of aircraft, engines and avionics systems developed in the country.

The Business-Led Network of Centres of Excellence (BL-NCE) innovation in the private sector, responding to real-world challenges with the right expertise. These extensive networks of cooperative research increase private sector investment’s in Canadian research and accelerate the transformation of laboratory ideas into vital solutions for the private sector.
Driving green aviation forward is essential to the health not just of our planet, but also of Canada’s aerospace industry and the 213,000 jobs and $25 billion of economic activity it generates each year. That’s why GARDN’s work in supporting collaborative projects that reduce the environmental footprint of the next generation of aircraft, engines and avionics systems is so important and why another year of successfully driving green technologies forward is such an accomplishment.

As you’ll read in this report, over the course of the past year GARDN has once again achieved significant results for the environment and for Canadian aerospace competitiveness. In this regard, GARDN has conducted an environmental assessment of the GARDN II Project Portfolio. Groupe Agéco came up to the conclusion that technologies developed under GARDN and its network of partners have the potential to account for 27% of Canada’s emission reduction target of 2030 (more in the following pages). GARDN has also successfully accomplished the mandate given by Environment and Climate Change Canada (ECCC) to draw an analysis of the status of sustainable aviation fuels in Canada and provided recommendations on how to spur innovation, development and production in this nascent sector for which our country has a great potential.

Since its second round of funding in 2014, GARDN has proved itself a key driver of collaboration and green R&D in the industry, bringing together over 29 companies, 20 research institutions, and 246 researchers on 20 collaborative research projects worth more than $20 million.

As GARDN concludes its final year, I wish to acknowledge the support of the Government of Canada and Business-Led Networks of Centres of Excellence Program for making these achievements possible. We are proud of our achievements in bringing all tiers of the green aviation sector together to facilitate greater participation and network growth, and we are confident that the fruit of our work will only become more apparent as the industry continues to move towards a greener, more sustainable future.

Finally, I would like to extend my appreciation to all the members of the network for your commitment in developing innovative green technology and processes for the aerospace sector. The successes in this report are your successes. Thank you for your dedication and support.

JIM QUICK
CHAIRMAN OF THE BOARD
PRESIDENT & CEO OF THE AEROSPACE INDUSTRIES ASSOCIATION OF CANADA (AIAC)
The GARDN team and I are delighted to present our annual corporate report 2018–2019.

The past year has been incredibly challenging and exciting for our organization as four major achievements may be counted between April 1, 2018 and March 31, 2019.

The first achievement is the collaboration with Natural Resources Canada. GARDN gathered the national SAF (Sustainable Aviation Fuel) industry stakeholders to a common goal being the acceleration of the production and use of SAF in Canada and to support the participants through the biojet fuel challenge. This collaboration was mentioned in our previous report as work began, however, we are pleased to see the process going through to the second stage of the challenge which will be detailed in PAGE 13.

The second achievement is pertaining to the SAF Community platform. This initiative was important for the nascent SAF sector as it allows for higher levels of outreach and information dissemination in a social media setting. The platform is not only available to Canadian stakeholders but also international players that can learn and share their experiences on SAF initiative. It will be beneficial to the global aviation sector (more info on the SAF Community platform on PAGE 12).

The third achievement is another diversification of revenue sources through a mandate by Environment and Climate Change Canada (ECCC). The International Civil Aviation Organization (ICAO) and others have stated that government intervention is a key to developing the supply of biojet fuel. It’s in this logic that ECCC has mandated us to produce a white paper on the state of the Canadian sector of SAF.

The fourth achievement that I’d like to put forward in this statement is the Environmental Assessment Report of the GARDN II Research Portfolio conducted by a third party, Groupe Agéco in collaboration with CIRAIG. This paper is the result of multiple efforts to undertake an evaluation process detailing the relevance and impact of the past four to five years of work and analyzing nineteen projects. The study showed that the benefits of greener technologies tend to grow over time and consequently stresses the relevance of programs such as GARDN to invest early in their development.

As the Business-Led Networks of Centers of Excellence won’t be renewed for GARDN (maximum of two mandates achieved), we are exploring paths for its future and taking advantage of this decade-long momentum and a bridge funding received from BL-NCE to keep our efforts until March 31, 2020.

I’d like to express my gratitude and thanks to GARDN’s partners, collaborators and management team for their work and passion to reduce the environmental footprint of Canada air transport.
The aviation industry was the 1st industry to set up goals to address the environmental impacts of its emissions.

**THE ENVIRONMENTAL OBJECTIVES OF THE INDUSTRY**

**GOAL 1**
An average annual improvement in fuel efficiency of 1.5% from 2009 to 2020

**GOAL 2**
A cap on net aviation CO₂ emissions at 2020 levels through a carbon-neutral growth

**GOAL 3**
Halving net CO₂ emissions by 2050, compared to 2005 levels

As mentioned in the right bottom part of the graph above, radical new technologies like electric propulsion aircraft and sustainable aviation fuels are paramount to achieving the objective of halving net CO₂ emissions by 2050.

Sustainable aviation fuels or ‘next-generation’ biofuels or ‘advanced’ biofuels all have similar intended meaning to denominate jet fuel produced from biological sources such (such as crops), cellulosic waste, algae, halophytes or non-biological sources such as used cooking oil and municipal solid wastes. It is important to highlight that fuels produced using these feedstocks can be unsustainable, depending on the methods used to produce the feedstocks and the processes to create the fuel, as sustainability is defined as something that can be continually and repeatedly resourced in a manner that conserves an ecological balance by avoiding depletion of natural resources and does not contribute to climate change.

As the characteristics of the alternative fuels are almost identical to those of conventional jet fuel, they can simply be mixed together and used in the same supply infrastructure without any engine or aircraft adaptation, which constitutes the definition of “drop-in fuels”.

GARDN is contributing to reaching these objectives by initiating important collaborative R&D projects that have laid the groundwork for the development of Canadian sustainable aviation fuels, the reduction of noise and the reduction of pollutants other than CO₂, such as NOₓ. GARDN’s research themes and projects are outlined in the next pages.
Following the first round of financing terminated in 2014, GARDN was granted more financing for a second round of five years until 2019. The new round, GARDN II, has kept the focus on the ongoing development of technology and procedures to achieve the environmental objectives of the global aerospace industry. Both programs, GARDN I and GARDN II, have jointly invested close to $70 million on research and development projects facilitating:

- Creativity and innovation in the development of greener aviation technology
- Collaboration between different-sized companies in the supply chain
- Funding in research institutions to train qualified personnel
- Life cycle of business projects and services factored into the environmental impact

GARDN has focused its development of green technologies and procedures following the three research themes:

**Quiet**
- Aircraft noise (airframe, landing gear)
- Engine noise (propeller, turbomachinery)
- Community noise
- Cabin noise

**Clean**
- Aircraft design and optimization to reduce fuel burn and climate change
- Advanced engine combustor concepts to reduce fuel burn, NO, and particulate matter
- Sustainable aviation fuels
- Optimized navigation and avionics

**Sustainable**
- Product end-of-life
- Green manufacturing and MRO
- Materials of concern
- Recycling
FACTS AND FIGURES OF THE YEAR

154 HQPs approximately have worked on GARDN projects this year. 12 are students—including 6 undergrads, 4 masters and 2 PhD students—and have been provided a hands-on experience in collaborative R&D projects and contributed immensely to the success of the projects.

52 MEMBERS in the network

28 COMPANIES 17 of which are SMEs

16 R&D research centers, colleges and universities

4 FEDERAL DEPARTMENTS AND AGENCIES

4 INTERNATIONAL ORGANIZATIONS

11 PROJECTS out of 19 are led by SMEs

2018-2019

6 POLICIES DEVELOPED

13 PROCESSES DEVELOPED

27 JOBS MAINTAINED in Canada

18 PAPERS were published this year, 8 of which are articles in refereed publications.

8 PROTOTYPES DEVELOPED

1$ funded by the NCE is matched by $1.4 from the industry.

5 BROKERED NEGOTIATIONS for new business

SUCCESS STORIES
GARDN mandated Groupe Agéco on a study on the environmental benefits from GARDN’s portfolio. The Environmental Assessment Report analyses the impact of the nineteen projects constituting the GARDN II Research Portfolio.

It confirms the importance of investing in the research and development of greener technologies in the aerospace sector to achieve the international and national climate change targets.

**GREENER CANADIAN AEROSPACE — A LOOK TOWARDS 2030**

*Download: GARDN Environmental Assessment Report*

**ESTIMATED ENVIRONMENTAL BENEFITS AT THE FLIGHT LEVEL**

For each technology cluster, the percentage below represents the reduction of the environmental metrics (i.e., the environmental benefits) of an aircraft flying with green technologies compared to a conventional aircraft.

<table>
<thead>
<tr>
<th>Technology Cluster</th>
<th>NRPEC</th>
<th>NO₂ / PM / SO₂</th>
<th>Noise</th>
<th>GHG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greener commercial turbofan</td>
<td>3%</td>
<td>3%</td>
<td>NA</td>
<td>3% per flight = 10 million passengers</td>
</tr>
<tr>
<td>SAF</td>
<td>13%</td>
<td>0-9%</td>
<td>NA</td>
<td>18% per flight = 9 million passengers</td>
</tr>
<tr>
<td>Electric glider</td>
<td>93%</td>
<td>37-93%</td>
<td>65%</td>
<td>95% per flight = 25,000 passengers</td>
</tr>
<tr>
<td>Unconventional configurations</td>
<td>13%</td>
<td>13%</td>
<td>16%</td>
<td>13% per flight = 3 million passengers</td>
</tr>
<tr>
<td>Other technology clusters</td>
<td>0.3-10%</td>
<td>0.3-31%</td>
<td>13-28%</td>
<td>0.3-10% per flight = 1 million passengers</td>
</tr>
</tbody>
</table>

**2018–2030 CUMULATIVE GHG BENEFITS AT THE FLEET LEVEL**

Scaled up to the fleet level, the cumulative GHG reductions of all clusters by 2030 correspond to...

- 20 million passengers
- Traveling between Toronto and Vancouver.

In 2016, Canada’s air traffic GHG emissions were equivalent to 66 million passengers travelling this distance.

**According to the report, SAF could contribute to a 18% reduction of greenhouse gases per flight, or reduce which is the equivalent of 9 million less passengers between Toronto and Vancouver.**

The report pointed out the challenges on the ongoing development of technologies and procedures for a cleaner, quieter and more sustainable aerospace industry. It is particularly relevant nowadays to concentrate and to rally all the industry members to reach the main targets of the aviation thanks to greener technologies.

“The technologies under study [in GARDN II portfolio] have the potential to contribute to 27% of the Canadian aviation’s carbon neutral growth target in 2030 and Sustainable Aviation Fuels identified as a key component of the success contributing to 98% of this effort.” (GARDN Environmental Assessment Report)
Canada is uniquely positioned with extensive natural, human and financial resources to successfully contribute to SAF volumes. The GARDN program is a unique opportunity for the public and private sectors to continue their efforts in strengthening the various supply chain components required for the Canadian air transport sector to achieve greater GHG reductions. In the end of 2018, Environment and Climate Change Canada (ECCC) has mandated GARDN to produce a report on the development of SAF in Canada. The report: Sustainable Aviation Fuels: A Canadian Perspective, provides the reader with a comprehensive overview of the accomplishments, the ongoing efforts and the current challenges faced in the road to a Canadian production of SAF.

GARDN has structured the White Paper around 6 strategic areas that we consider fundamental for the development and production of Canadian-made SAF and their supply chains from feedstock, conversion, distribution and all the way to the end user. The 85-page document provides recommendations that are addressed to both the private and public sectors. Some of them require specific guidance from the federal and provincial governments and others may be tackled by the straightforward leadership of the industry.

A few examples are provided below:

- **STRATEGIC AREA 1 :** RD&D and innovation: Set innovation strategy targets for SAF development and encourage the development of feedstock-agnostic conversion technologies.
- **STRATEGIC AREA 2 :** Financing and strategic partnerships: De-risk private and public investments with a coordinated approach between federal and provincial.
- **STRATEGIC AREA 3 :** Policy and regulations: Engage stakeholders through demonstration initiatives across Canada to facilitate SAF integration into the existing transport, storage and distribution infrastructure.
- **STRATEGIC AREA 6 :** Consortia-building and regional initiatives: Encourage the development of bioports and other multi-stakeholder regional projects and initiatives.

**OBJECTIVES**

Accelerate the Canadian transition to a low-carbon economy while increase aviation’s contributions to the UN Sustainable Development Goals (SDGs).

**PILLARS**

- Bioeconomy
- Circular economy
- Strategic eco-design
- Whole system design
- Industrial symbiosis

**TO HELP THE DEVELOPMENT OF THE SAF SECTOR IN CANADA, THERE IS A NEED TO CREATE A BETTER KNOWLEDGE-TRANSFER STRATEGY TO HELP THE STAKEHOLDERS ALL ALONG THE SUPPLY CHAIN UNDERSTAND LOCAL GROWTH OPPORTUNITIES.**

More to read by clicking on the following link: [https://safcommunity.org/page/white-paper](https://safcommunity.org/page/white-paper)
In October 2018, GARDN officially launched its online platform dedicated to sustainable aviation fuels, SAF Community, to gather stakeholders of the SAF sector and foster collaborations from the feedstock producer to the end user. Its mission is to provide users with the latest news and information resources on SAF development and aims to facilitate community members to exchange ideas, opinions and expertise. The platform is open to worldwide players but mainly active in North America to ensure a better global contribution to accelerating the innovation and development of SAF.

“We hope to enable users to easily find the right expertise and collaborators to get engaged in discussion groups, collaborative projects, events, etc.... through the platform as the demand for gathering in the industry is growing.”

2019

A FEW NUMBERS

168 USERS were registered on the platform database

43% OF USERS are from Canada

https://safcommunity.org
The Sky’s the Limit Challenge was created to stimulate the development of a SAF supply chain to further reduce the Canadian aviation industry’s GHG emissions and lower its environmental footprint. This Challenge is part of Natural Resources Canada’s $75-million initiative to launch five clean-tech challenges to drive innovation and accelerate the clean-growth economy. NRCan has engaged a wide range of partners to support a SAF supply chain in Canada. Among those, WestJet and Air Canada will play key roles by serving as carriers for the Cross-Canada Flight Competition. NRCan has also partnered with GARDN to promote the challenge, engage with its community and facilitate participation. The Challenge is expected to foster research into new feedstock sources and refining processes as well as de-risk public and private SAF investments in Canada.

THE CHALLENGE CONSISTS OF TWO COMPETITIONS:

- First, the Green Aviation Fuels Innovation Competition provides $2 million apiece for four teams to develop the most innovative solutions, which, in turn, will support their next endeavour: an 18-month competition to produce the most economical and environmentally sustainable aviation fuel and win the $5 million grand prize.
- Second, the Cross-Canada Flight Competition, in which the first participant to fuel a Canadian commercial flight using a minimum 10% blend of made-in-Canada SAF will win $1 million.

Overview of the Sky’s the Limit Challenge

<table>
<thead>
<tr>
<th>Stream 1: Green Aviation Fuels Innovation Competition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consortia building</strong></td>
</tr>
<tr>
<td><strong>Consortia puts plan into action</strong></td>
</tr>
<tr>
<td><strong>Top 4 teams announced</strong></td>
</tr>
<tr>
<td>$2M for each team</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
</tr>
<tr>
<td>Establish and demonstrate supply chain linkages</td>
</tr>
<tr>
<td>Prove technology by producing a testable quantity of SAF</td>
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<tr>
<td>Provide credible cost and GHG projection based on production</td>
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<tr>
<td>Develop clear path towards scale up and commercialization</td>
</tr>
<tr>
<td>Articulate benefits for Canada (e.g., jobs)</td>
</tr>
<tr>
<td><strong>Grand prize $5M</strong></td>
</tr>
<tr>
<td>To the most economically and environmentally sustainable approach for scaling up SAF production in Canada</td>
</tr>
<tr>
<td><strong>Final submission 10 L SAF</strong></td>
</tr>
<tr>
<td><strong>Call for proposals opens</strong></td>
</tr>
<tr>
<td>August 2018</td>
</tr>
<tr>
<td><strong>Call closes</strong></td>
</tr>
<tr>
<td>February 2019</td>
</tr>
<tr>
<td><strong>Competition begins</strong></td>
</tr>
<tr>
<td>March 2019</td>
</tr>
<tr>
<td><strong>Competition closes</strong></td>
</tr>
<tr>
<td>May 2019</td>
</tr>
<tr>
<td><strong>$1M winner announced</strong></td>
</tr>
<tr>
<td>November 2020</td>
</tr>
<tr>
<td><strong>Final submission 10 L SAF</strong></td>
</tr>
<tr>
<td>January 2021</td>
</tr>
<tr>
<td><strong>Competition closes</strong></td>
</tr>
<tr>
<td>March 2021</td>
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<table>
<thead>
<tr>
<th>Stream 2: Cross-Canada Flight Competition</th>
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</thead>
<tbody>
<tr>
<td><strong>Competition begins</strong></td>
</tr>
<tr>
<td>Meet all the criteria for a ‘Made-in-Canada’ sustainable aviation fuel for a cross-Canada Air Canada / WestJet commercial flight</td>
</tr>
<tr>
<td><strong>Competition closes</strong></td>
</tr>
<tr>
<td><strong>$1M winner announced</strong></td>
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</table>
GARDN has brought together its community in Ottawa’s Shaw Center for a two-day conference in November 2018 held in conjunction with the Canadian Aerospace Summit and the Transport Canada Delegates Conference. The event was an opportunity to learn more about the projects undertaken by the network and better integrate cross-sectoral strengths to accelerate the development of aircraft designs, engines, avionics systems and fuels. The conference had a dedicated forum to give participants an overview of the Sky’s the Limit Challenge, followed by a panel discussion on key issues for applicants and the possibility to receive advice from producers, investors and financial experts.

During the presentations, several stakeholders introduced their current work and projects to be submitted to the Challenge. They also had the opportunity to identify their own strengths and capacities, and network with potential partners. Informative sessions were dedicated to analyzing the GHG aviation trends in Canada and reduction scenarios using SAF, supply chain logistics and enabling policies and regulations.

A total of 180 participants were registered from which 88% were satisfied/very satisfied. 84% of the participants were from the industry, 14% from governments and academia and the 2% remaining were students. The post-conference survey conducted also pointed out that for 63% of the participants, the first reason they attended the conference was the Sky’s the Limit Challenge forum, which shows that SAF-only related events could be appealing and interesting for the industry and confirms that Sustainable Aviation Fuels are the key component for a greener aviation.

“There was optimism in the room around the potential to produce biojet fuel, attract investment and form lasting partnerships in Canada”. (Jason Gadoury, Natural Resources Canada)
**2018**

**September 04.**

**BC SMART IN VANCOUVER**

**October 02.**

**ATAG GLOBAL SUSTAINABLE AVIATION SUMMIT IN GENEVA**

**October 26.**

**THE 8TH NATIONAL SYMPOSIUM ‘ENVIRONMENT IN THE COURTROOM’**

Enforcing Canadian GHG Emissions Laws’ in Quebec city: The symposium aimed at strengthening court practitioners’ legal knowledge on enforcement issues related to the regulation of Canadian GHG emissions.

**November 05.**

**SCALING UP CONFERENCE IN OTTAWA**

GARDN attended the conference to increase the visibility of NRCan’s Challenge and learn from the bioeconomy experts at large.

**November 14.**

**IATA ALTERNATIVE FUEL SYMPOSIUM IN SINGAPORE**

GARDN had a presentation focused on GARDN and NRCan’s Sky’s the Limit Challenge. The objective was to raise awareness about the Challenge and inform on the Canadian initiatives taking place in this sector.

**December 05.**

**RSB ANNUAL MEETING IN BERLIN**

As a member of Chamber 5, UN, Governments & Research, GARDN attended the Roundtable on Sustainable Biomaterials (RSB)’s annual meeting to discuss the challenges, including aviation’s, pertaining to sustainability certifications for the protection of ecosystems.

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**2019**

**December 18.**

**WORKSHOP CRIBIQ–CRIAQ IN MONTREAL**

Workshop by the Consortium de recherche et innovations en bioprocédés industriels au Québec (CRIBIQ) and the Consortium de recherche et d’innovation en aérospatiale au Québec (CRIAQ) on SAF supply chain: GARDN co-organized on the one-day workshop to present NRCan’s Challenge and identify the gaps and challenges faced by the sector in the province of Quebec.

**February 06-07.**

**AQPER SYMPOSIUM**

Presentation by Sylvain Cofsky on green transportation: introduction of GARDN, the Sky’s the Limit Challenge and the SAF Community platform.

**February 22.**

**SA2GE WORKSHOP IN MONTREAL**

The Coalition for Greener Aircraft, a non-profit organization dedicated to developing smarter, more efficient and effective technologies has organized a half-day training on Ecodesign, a Driver of Innovation for Organizations. During this event, GARDN had the opportunity to present its work and the narrative behind the efforts to develop the production of Canadian sustainable aviation fuels supply.

**March 05.**

**RSB × SAF COMMUNITY WEBINAR ON SUSTAINABILITY CERTIFICATION**

GARDN had a webinar focused on sustainability certifications provided by RSB in the SAF sector. The call was an opportunity for participants to learn more about the offer of RSB in this regard, its importance and how to implement such an initiative.

**March 26.**

**AMERICANA IN MONTREAL**

GARDN gave a 15-minute presentation about the past, present and future states of the sustainable aviation fuels in Canada and the need to develop a SAF sector in Canada.
<table>
<thead>
<tr>
<th>Code</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA-21</td>
<td>Experimental Validation of Innovative Environmentally Focused Aircraft Configurations</td>
</tr>
<tr>
<td>BA-22</td>
<td>Airframe Noise Reduction for Business and Commercial Aircraft</td>
</tr>
<tr>
<td>BA-23</td>
<td>Experimental Validation of Innovative Environmentally Friendly Aircraft Configurations—Extension for Noise Measurements</td>
</tr>
<tr>
<td>BC-21</td>
<td>Reuse of Uncured Aerospace Preimpregnated Composite Materials in Commercial Applications</td>
</tr>
<tr>
<td>CMC-21</td>
<td>Flight Management Performance Optimization II</td>
</tr>
<tr>
<td>CMC-22</td>
<td>Flight Management Performance Optimization III</td>
</tr>
<tr>
<td>HD-21</td>
<td>Additive Manufacturing for Landing Gear</td>
</tr>
<tr>
<td>NEC-21</td>
<td>Assessment of Likely Technology Maturation Pathways Used to Produce Biojet from Forest Residues (ATM Project)</td>
</tr>
<tr>
<td>NU-21</td>
<td>Energy-Efficient Aircraft Configurations and Concepts of Operation</td>
</tr>
<tr>
<td>OPT-21</td>
<td>Development of an Electric Propulsion System to Convert Gliders for Self-Launch Operations to Reduce the Environmental Footprint</td>
</tr>
<tr>
<td>PWC-22</td>
<td>Ongoing</td>
</tr>
<tr>
<td>PWC-23</td>
<td>Noise Reduction for the Next-Generation Regional Turboprop</td>
</tr>
<tr>
<td>PWC-24</td>
<td>Ongoing</td>
</tr>
<tr>
<td>PWC-25</td>
<td>Development of Innovative Aerodynamics Performance Enablers for Gas Turbine Engine Compressors</td>
</tr>
<tr>
<td>QC-21</td>
<td>Greening the Aerospace Supply Chain</td>
</tr>
<tr>
<td>SRS-21</td>
<td>Turboprop Flight Advisory System (FAS) for Cruise Fuel Burn Reduction / Turboprop Flight Advisory Systems Enhancements, Testing and Engine Model Development</td>
</tr>
<tr>
<td>SRS-22</td>
<td></td>
</tr>
<tr>
<td>WG-21</td>
<td>Canada’s Biojet Supply Chain Initiative: Enabling 2020 Carbon Neutral Growth</td>
</tr>
<tr>
<td>WG-22</td>
<td>Civil Aviation Alternate Fuel Contrail and Emissions Research</td>
</tr>
</tbody>
</table>
In this project, wind tunnel data compared against computational fluid dynamics (CFD) allowed the partners to calibrate their predictions of aerodynamic coefficients both at high and low fidelity. Furthermore, partners have gained an understanding of the uncertainty between different CFD methods and wind tunnel data, which will educate the use of design margins in future design work. The design partners are working on has the potential to decrease CO$_2$ emissions by 15–20%.

High Lift Noise Reduction: New slat noise tonal source identified—10 dB tone over background on slat noise. High lift efforts to evaluate means of suppression;

Slat Noise: Slat junction source noise reduction of 3 dB; 1 dB reduction of slat noise through application of MPP;

Flap Noise Reduction: MPP combined with best geometric design practices learned resulted in a 2 to 4 dB;

Landing Gear Noises Reduction: 1 to 2 dB reduction based on best practices learned;

Material Development for Noise Reduction: Key materials were evaluated to progress the technology to the level it could be applied on an aircraft.

In continuation of the BA-21 project, the team has:

* Successfully developed a miniature monopole source;
* Validated by NRC Anechoic testing capabilities;
* Collected noise scattering data sets around conventional and un-conventional aircraft for improvement of Semi-Empirical methods;
* Understood the limitations of BEM modeling on large models and a clear direction for future modeling established.

Post GARDN work is undergoing to predict shielding and develop improved models.
BC-21

REUSE OF UNCURED AEROSPACE PREIMPREGNATED COMPOSITE MATERIALS IN COMMERCIAL APPLICATIONS

ONGOING

* Development of potential commercial use for typical waste products from aerospace composite producers which would result in significant reduction in waste costs for composite producers;
* Development of new processes which could be used for aesthetic (non-structural) components within the aerospace sector to increase material utilization;
* Potential development of low-cost competitor to prepreg products, such as HexMC™.

CMC-21

FLIGHT MANAGEMENT PERFORMANCE OPTIMIZATION II

COMPLETE

In this project featuring CMC and École de Technologie Supérieure, 4 tasks were tackled with different environmental impacts each:

* Flight trajectory optimization (optimization of the lateral and vertical flight trajectories resulting in lower aircraft operating cost, shorter flight time, reduction of the crew workload and increased flight safety for total reductions of up to 2.77 tons of CO$_2$ for a typical long-haul flight);
* Optimal flight trajectory based on meteorological data (the flight trajectory optimizer makes use of a 4-D wind grids to increase weather input inaccuracies allowing reducing flight time, fuel burn and aircraft operating cost and representing a typical reduction of 302 kg of CO$_2$ for a 1890-mile flight);
* Implementation of Required Time of Arrival (RTA) constraint (4 kg of fuel reduction over 1400 NM which represents app. 44 kg of CO$_2$ reduction);
* Performance Database (PDB) Creation.

CMC-22

FLIGHT MANAGEMENT PERFORMANCE OPTIMIZATION III

COMPLETE

The algorithm developed by the LARCASE team (ETS) and validated using actual and realistic atmospheric data provided by Environment Canada is able to collect information during the flight from various avionics systems aboard the aircraft and perform various analyses to estimate the actual performance of the aircraft without requiring detailed performance characteristic from the aircraft manufacturer. The results can also used to evaluate the accuracy of the aircraft model encoded in the FMS (usually based on aircraft manufacturer performance figures). When the algorithm detects significant errors between the FMS predictions and the measured performance during the flight, a correction is automatically applied to update the model in order to increase flight predictions accuracy, thus providing an increase performance of the optimization functions.

In addition, modifications applied to the FMS software allow military customers to take advantage of FMS optimization functions, and therefore allow the optimized solution to be deployed to a larger number of aircraft.
To demonstrate that an additively manufactured landing gear component can be flight-tested, the project team is working on the best design to manufacture 2 prototypes. Manufacturing and quality plans have been drawn up. The team is working towards assessing the commercial performance of the AM landing gear towards the end of 2019. The consortium is trying to find new technologies that allow production quality control and costs reduction. This is due to the fact that current technologies used for AM are pretty expensive and not scalable to production. A flight test is being discussed with Embraer outside of GARDN’s project scope. The project team will keep working on the project after GARDN’s scope.

Biocrudes produced using several different direct thermochemical liquefaction (TL) technologies and then upgraded by hydrotreatment, were demonstrated to contain a significant fraction of jet-range fuel. The biojet fractions were analyzed and demonstrated a high level of compliance with general standards for jet fuel based on ASTM certification requirements. Assessment of potential emission reductions of these biojet production pathways through life cycle analysis demonstrated that significant emission reductions were possible with many of the pathways.

This project has investigated novel air vehicle configurations, advanced propulsion systems and noise reduction techniques to enable cleaner and quieter UAV operations and air transportation by:

- Reducing fuel consumption: smaller and more efficient engine for cruise operating points for which distributed propulsion can enable more advanced configurations with additional potential benefits such as blown wings or VTOL configurations that can fly in fixed wing mode;
- Reduced footprint: reduce noise (and vibration) when hybrid is run on full electric, allowing low observability/impact in operations such as wildfire and environmental monitoring;
- Greener and cleaner operation: temperature differentials and energy harvesting using floating flaps may yield usable amounts of energy for on-board systems while reducing cooling drag by actively cooling cylinder heat and muffler.
The OPT-21 team has:

- Demonstrated the feasibility of retrofitting a certified glider with an electric propulsion system for self-launch capabilities;
- Proposed a certification basis for a certified electric glider in Canada;
- Highlighted the certification challenges of electrical propulsion in Canada;
- Increased the level of technical knowledge on the topic of electric propulsion units for the civil aviation sector in Canada;
- Demonstrated the potential noise reduction to use an electrical powertrain in comparison with conventional internal combustion engine.

The project was erected with four work packages, each has different TRL targets:

- Integrated Powerplant Noise Reduction: established a higher fidelity model to evaluate the impact of large turboprop aircraft noise on the environment and to assess noise reduction features;
- Low Noise Propeller Design: developed new capabilities to assess parametrized propeller noise and feedback to a/c level noise impact, established CFD based parametric knowledge database of propeller and installation effects; developed an analytical tool to predict propeller noise;
- Advanced Duct & Liner Technology: developed new liner type tailored to turboprop application; performed rig testing on coupons; enhanced analytical tool for liner modeling and design;
- Low Noise Engine Demonstration: procure a full-scale inlet duct acoustics; perform rig testing to characterize acoustics; Execute an engine test for demonstration (2020).

Over 13 papers presented or published in international conferences and journals.
**PWC-23**

**NEXT-GENERATION COMBUSTOR FOR SMALL GAS TURBINE ENGINES**

**ONGOING**

- Evolve current low-emission technology to the next-generation turbo-props by a new combustor system. The new system is an enabler for GHG emissions reductions and has the potential to deliver significant reductions of NO\textsubscript{x} and particulate matter while improving component life:
  - Adapt low emission combustor technology to Next-Gen Turboprops;
  - Invent low-emission fuel nozzle performance;
  - Advance modeling and analysis of effusion cooling;
  - Develop new manufacturing methods of complex aerospace parts for combustion system.

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**PWC-24**

**DEVELOPMENT OF INNOVATIVE AERODYNAMIC PERFORMANCE ENABLERS FOR GAS TURBINE ENGINE COMPRESSORS**

**COMPLETE**

In this project, partners have been able to:

- Establish of a new design methodology for rotor with lower performance and surge margin sensitivity to tip clearance increase;
- Design, manufacture and commission a new transonic compressor test rig that can be used in the future aerodynamic research;
- Design, build and test the new rotor and casing treatment technologies for reducing performance and stall margin sensitivity to rotor tip clearance increase.

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**PWC-25**

**AERO-GAS TURBINE ENGINE EXHAUST NON-VOLATILE PARTICULATE MATTER (nvPM) EMISSION BASELINE MEASUREMENT AND MODELING**

**ONGOING**

- Measure nvPM on P&WC turbofan engines;
- Report nvPM measurements to ICAO;
- Develop nvPM/soot models with chemical kinetics, soot aerosol dynamics and radiation transports.
**QC-21**

**GREENTHE AEROSPACE SUPPLY CHAIN**

**COMPLETE**

- Successfully conducted a first ever survey on the ‘state of green practices’ in the Canadian aerospace;
- Successfully identified opportunities for Green procurement specifications and Design for Environment in 3 priority clusters: avionics, standard parts, composite;
- Developed the first GSMC framework for the aerospace sector;
- Contribute to capacity building/education in each participating organization and increased awareness (in all the supply chain) on the topic of green products and technologies;
- Successfully demonstrated the potential of a network effect, since the project involved a SME, a university, 3 OEMs and an industrial association, all working together and sharing best practices.

**SUSTAINABLE**

**GREENING THE AEROSPACE SUPPLY CHAIN**

**SRS-21 / SRS-22**

**Turboprop Flight Advisory System (FAS) for Cruise Fuel Burn Reduction / Turboprop Flight Advisory Systems Enhancements, Testing and Engine Model Development**

**COMPLETE**

- Further developed the iPad Flight Advisory System app developed in SRS-21 with its partners Carleton University and AeroSafety. A single-engine turboprop aircraft model and enhanced meteorological data were added to the app. Both single- and twin-engine aircraft models were validated with flight data thanks to the University of Sherbrooke and North Wright Airways Ltd. An engine thermodynamic model for cruise conditions was developed and implemented into the app, supporting a more generalized approach to fuel burn calculation. An aircraft dynamics model was also developed, and an analysis of engine dynamics on fuel burn was conducted.
- Up to 10% in block fuel burn savings and commensurate CO₂ emissions reductions were calculated based on actual flight data.
WG-21

CANADA'S BIOJET SUPPLY CHAIN INITIATIVE (CBSCI): ENABLING 2020 CARBON NEUTRAL GROWTH

COMPLETE

Canada’s Biojet Supply Chain Initiative (CBSCI) achieved the objectives of:

* Completing the first-ever introduction of biojet (SAF) into the hydrant blending system of Canada’s largest airport (Toronto Pearson International Airport) in support of Earth Day 2018;
* Generating hands-on operational experience and disseminating it for sector advancement via the project website: cbsci.ca;
* Increasing biojet policy relevance in Canada by demonstrating its operational feasibility and ability to generate GHG reductions. HEFA biojet is now being actively considered as a compliance pathway under the federal Clean Fuel Standard and provincial low-carbon fuel regulations;
* Providing 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;
* Completing technical analyses to support the use of domestic feedstocks in HEFA biojet production.

WG-22

CIVIL AVIATION ALTERNATE FUEL CONTRAIL AND EMISSIONS RESEARCH (CAAFCER)

COMPLETE

Civil Aviation Alternate Fuels Contrails and Emissions Research (CAAFCER) achieved the goals of:

* Comparing the characteristics of persistent contrails formed from petroleum jet fuel and biofuel through a series of 5 commercial biofuel flights with following measuring aircraft (NRC CT-133) analyzing contrail composition;
* Advancing the state of science of contrail research and Canadian contribution in this field;
* Enabling the efficient introduction of biojet into the fuel operations of Montréal-Pierre Elliott Trudeau International Airport;
* Disseminating project results via cbsci.ca.
Sylvain Cofsky has joined GARDN and taken its reins in 2009. Since then, GARDN has become the leading aviation network centered on reducing the environment impact of a major Canadian industry. This initiative not only serves the environment but also the industry in strengthening its competitive advantage. Consequently, it's important for GARDN's management, the Networks of Centers of Excellence, GARDN's founding members, the industry, academia and research centers that worked with GARDN from the start to our present day to thank Sylvain for all his hard work, dedication, belief and aspiration to push the network further and achieve the great momentum we experience today. Below are testimonies from members of the Board of Directors who worked closely with Sylvain throughout the years.

Thank you Sylvain

“Thank you Sylvain. Your efforts put GARDN on the map internationally. At home, you were the steady hand that kept GARDN running smoothly.”

REX HYGATE
Business Development Manager at Esterline Avionics, CMC Electronics

“GARDN’s success has been in large part due Sylvain’s belief and commitment to the mission of GARDN. A mission we can proudly say we achieved.”

MICHEL DION
Innovation Director, Bell

“Sylvain’s leadership, commitment and passion for green aviation has been key to the success of GARDN. Thought this achievement, GARDN has set the path for Canadian green aviation initiatives. Thank you!”

HAYLEY OZEM
Manager, Combustion Component Center, Pratt & Whitney Canada Corp.

“Sylvain has been integral in leading GARDN to help Canada set goals, prioritize technology, support research, and have measurable deliverables to achieve a more sustainable, green aviation industry. His energy and commitment to sustainability was outstanding and appreciated by everyone who had the privilege to work with him.”
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