AGENDA

BOMBARDIER STRATEGIC TECHNOLOGY

1. BOMBARDIER, A HISTORY OF INNOVATION
2. ENVIRONMENTAL GOALS FOR AVIATION
3. IATA TECHNOLOGY ROADMAP
4. EUROPEAN AND US VISIONS
5. SETTING AVIATION ENVIRONMENTAL STANDARDS
6. GLOBAL EXPRESS AND CSERIES TECHNOLOGY FOR THE ENVIRONMENT
7. CONCLUSIONS
Our founder, Joseph-Armand Bombardier, devoted himself to build a vehicle that could solve the problem of individual transportation on snow and end the isolation of rural communities.

Bombardier has consistently responded to challenges and opportunities with tireless innovation, daring creativity and entrepreneurial gusto.

Nearly 70 years helping communities connect and prosper with snowmobiles, trains and planes.
Bill Lear started Learjet in Wichita in 1962. He held more than 150 patents.

The Short brothers (Eustace, Oswald and Horace) established the first British airplane manufacturing company in 1908. In 1909, they manufactured, on license from Wilbur Wright six Wright planes in Britain.

Sir Geoffrey de Havilland
De Havilland in 1920 formed the de Havilland Aircraft Company in Britain, where he and his company designed and built a large number of aircraft. The Canadian subsidiary was created in 1928.
# BOMBARDIER AEROSPACE

## 30 AIRCRAFT LAUNCHED SINCE 1989

|-------------------|--------------------|-------------------|----------------|-------------------|-------------|

GLOBAL VISION (LAUNCHED 2007), G7000 AND G8000 FAMILY (LAUNCHED 2010), LEARJET 70 & 75 (LAUNCHED 2012) NOT ILLUSTRATED
STRATEGIC TECHNOLOGY

- THE NECESSARY FIRST STEP IN THE INNOVATION CHAIN

Technology development & transfer (Industry - University Collaborations)

Advanced Studies (University Contracts)

Technology demonstration & validation (Pre-launch activities in Innovation Center)

Product Development (APDC)

Cost

Time

Brake even Point

R&T costs

10% 40% 50%

-10 -5 0 +5 +10 +30

Program Launch

Strategic Technology
WHAT DRIVES TECHNOLOGY INNOVATION AT BOMBARDIER?

Performance / Economics
E.g. Operational capabilities, availability

Passenger requirements
E.g. Comfort, Connectivity

Environmental concerns
E.g. Hazardous materials, Emissions (Noise, CO2, NOx), Lifecycle assessment
ENVIRONMENTAL GOALS FOR AVIATION

TO LIMIT OR REDUCE...

- Mostly CO₂

- Global climate
  ...the impact of aviation greenhouse gas emissions on the global climate

- Community Noise
  ...the number of people affected by significant aircraft noise.

- Air Quality
  ...the impact of aviation on local air quality

- dBs

- HC
- CO
- NOₓ

+ End of Life!
ENVIRONMENTAL GOALS FOR AVIATION
WORLD-WIDE MAN-MADE CO₂ EMISSIONS

- Energy supply: 26%
- Buildings: 8%
- Waste: 3%
- Transportation: 13%
- Rail, ships and others: 1%
- Industry: 19%
- Agriculture: 14%
- Forestry: 17%
- Commercial Aviation: 98%
- Business Aviation: 2%

Road: 10%
ENVIRONMENTAL GOALS FOR AVIATION
AVIATION INDUSTRY COMMITMENT

- Achieving carbon-neutral growth by 2020
- Improving fuel efficiency by an average of 1.5% per year from 2009 to 2020
- Reducing CO₂ emissions by 50% by 2050, relative to 2005

Four Key Enablers

1. Technology
2. Alternative Fuels
3. Operations and Infrastructure
4. Economic Measures
SOURCES OF LIFECYCLE CARBON REDUCTIONS
IN PERCENTAGE OF 2005 BASELINE

TECHNOLOGY
EXPECTED CO₂ EMISSION REDUCTIONS FOR NEW AIRCRAFT

OPERATIONS AND INFRASTRUCTURE
EXPECTED CO₂ EMISSION REDUCTIONS FOR IN-SERVICE AIRCRAFT

ALTERNATIVE FUEL
EXPECTED CO₂ EMISSION REDUCTIONS FOR IN-SERVICE AIRCRAFT
TECHNOLOGY IMPROVEMENT REQUIREMENTS

ENVIRONMENTALLY FOCUSED AIRCRAFT RESEARCH

2005 Baseline Year

% Fuel Burn Improvement

- 2005 Baseline Year
- 2005 (Baseline)
- GX (1998)
- 2012
- 2020
- 2035
- 2050

Emissions (100% Index Equals 2005 Levels)

- CO₂ Emissions
- Technology
- Operations & Infrastructure
- Alternative Fuels

Timescale

- 2005 Baseline Year
- GX (1998)
- 2012
- 2020
- 2035
- 2050

Fuel Burn Improvement

- 2005: 10%
- 2012: 20%
- 2020: 32%
- 2035: 45%
- 2050: 45%

 Engines (13%)
 Systems (6%)
 Structure (9%)
 Configuration (16%)
 Composite Structures
IATA TECHNOLOGY ROADMAP
POSSIBLE TIME FRAME FOR TECHNOLOGY INSERTION – AIRFRAMES & SYSTEMS

- Riblets
- Wireless optical connections for IFE
- Spiroid wingtip
- Advanced fly-by-wire
- MEA architecture
- Variable camber with new control surfaces
- Energy harvesting devices
- Natural laminar flow
- Hybrid laminar flow control
- Hybrid wing body
- Truss-braced wing
- Cruise-efficient STOL
- Wireless flight control system
- PEM fuel cell
- Solid-oxide fuel cell
- Solid acid fuel cell
- Morphing materials
- Morphing airframe

Featured on CSeries!
IATA TECHNOLOGY ROADMAP
POSSIBLE TIMEFRAME FOR TECHNOLOGY INSERTION - ENGINES

Engine replacements
- Geared turbofan
- Advanced direct drive
- Counter-rotating fan
- New engine core concepts
- Open rotor / unducted fan
- Advanced 3rd gen. core
- Active stability management
- Thermal management
- Variable cycle
- Adaptive cycles
- Boundary-layer ingesting inlets
- Embedded distributed multi-fan
- Adaptive / active flow control
- Ubiquitous composites
- Non-Brayton cycles
- Pulse detonation cycles
- Regenerative / recuperative cycle

2010
2020
2030

Featured on CSeries!
IATA TECHNOLOGY ROADMAP
POSSIBLE TIMEFRAME FOR TECHNOLOGY INSERTIONS – FUELS AND ATM

Alternative Fuels
- Biomass to fuel or biojet
- Synthetic paraffinic kerosene
- Biodiesel
- Furans
- Transesterification fuels
- Butanol
- Liquefied petroleum gas
- Liquid methane
- Compressed natural gas
- Ethanol
- Liquid hydrogen

Air Traffic Management
- Data link communication
- Required time of arrival
- Performance-based navigation
- Automatic dependent surveillance broadcast - OUT
- System-wide information management
- GNSS landing system via ground based augmentation system
- Automatic dependent surveillance broadcast - IN

Feature on New Bombardier Aircraft!
1. In 2050 technologies and procedures available allow a 75% reduction in CO2 emissions per passenger kilometre to support the ATAG target and a 90% reduction in NOx emissions. The perceived noise emission of flying aircraft is reduced by 65%. These are relative to the capabilities of typical new aircraft in 2000.

2. Aircraft movements are emission-free when taxiing.

3. Air vehicles are designed and manufactured to be recyclable.

4. Europe is established as a centre of excellence on sustainable alternative fuels, including those for aviation, based on a strong European energy policy.

5. Europe is at the forefront of atmospheric research and takes the lead in the formulation of a prioritised environmental action plan and establishment of global environmental standards.
### US High Level Environmental Goals

**NASA Environmentally Responsible Aviation Project**

<table>
<thead>
<tr>
<th>Technology Benefits*</th>
<th>Technology Generations (Technology Readiness Level = 4-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise (cum margin rel. to Stage 4)</td>
<td>-32 dB</td>
</tr>
<tr>
<td>LTO NOx Emissions (rel. to CAEP 6)</td>
<td>-60%</td>
</tr>
<tr>
<td>Cruise NOx Emissions (rel. to 2005 best in class)</td>
<td>-55%</td>
</tr>
<tr>
<td>Aircraft Fuel/Energy Consumption† (rel. to 2005 best in class)</td>
<td>-33%</td>
</tr>
</tbody>
</table>

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**Technical Challenges**

- Reduce Drag, Weight, TSEC, Emissions and Noise

- **Tailored Fuselage**
- **High AR Elastic Wing**
- **Quiet, Simplified High-Lift**
- **High Eff. Small Gas Generator**
- **Hybrid Electric Propulsion**

- **Propulsion Airframe Integration**
- **Tools**
- **Alternative Fuels**
- **Research Areas**
ICAO is under pressure to do things differently.

There is pressure from the community to set “technology-forcing” standards and regulations.

A group on CO2, Climate Change and Fuel Burn was formed in 2009 to come with realistic goals and certifiable standards:

- Predict technologies that may be available in 2020/2030
- Integrate these technologies into resized aircraft and evaluate the benefits
- Create a metric to measure fuel burn performance
- Present this information for decision makers

The results will impact future commercial fleet: operating costs, noise, emissions.

TS1: Evolutionary technology Improvements

TS2: Average regulatory pressure: revolutionary technology developments

TS3: Extreme regulatory pressure

SOURCE: JUAN ALONSO, UTIAS CLIMATE CHANGE WORKSHOP 2012
One of the most competitive aspects of aviation is **PRODUCT DIFFERENTIATION**.

Large investments in clean aircraft technologies in leading aviation countries indicate that **the greatest differentiator for future aircraft will be the ENVIRONMENTAL FOOTPRINT**.

Bombardier’s family of aircraft are designed for low environmental footprint.

- **Global 7000/8000**, scheduled to enter service in 2016, offers a 14% reduction of fuel burn in comparison to the Classic Global technology.

- **CSERIES**, scheduled to enter service in 2013, is expected to offer a 20% fuel burn CO2 emissions reduction compared with current aircraft, through several technology advances:
  - Pratt & Whitney’s geared turbofan,
  - Use of advanced structural materials, making up 70% of the airframe,
  - Advanced aerodynamic design, featuring a numerically optimized fourth generation transonic wing,
  - Advanced systems, including full fly-by-wire, electric brakes and a navigation system ready for NEXTGEN and SESAR.
GLOBAL COMMITMENT TO THE ENVIRONMENT
BUSINESS JETS SEGMENT IN THE 5,200 NM TO 7,900 NM RANGE

Global
Super Large
Business Jets

Launched
GLOBAL 8000
Range: 7,900 nm
HSC: M0.90
Cabin Vol.: 2,236 cu. ft

Launched
GLOBAL 7000
Range: 7,300 nm
HSC: M0.90
Cabin Vol.: 2,316 cu. ft

In production
GLOBAL EXPRESS XRS
Range: 6,150 nm
HSC: M0.88
Cabin Vol.: 2,637 cu. ft

In production
GLOBAL 5000
Range: 5,200 nm
HSC: M0.88
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GLOBAL COMMITMENT TO THE ENVIRONMENT

Reduced Waste
- Digital designs and publications
- Optimized processes for manufacture reduce scrap material and increase efficiency

Elimination of Hazardous Materials and Processes
- Lead free solder used
- Non-CFC cleaners for production
- CAD plating avoided

Reduced Emissions
- Powerplant NOx emissions outperform future CAEP/6 ICAO regulations by 50%
- APU NOx emissions outperform ICAO by 40%

High Efficiency Engines
- Deliver the ability to travel further than any aircraft in the equivalent class

Performance Based Navigation
- Smoother traffic flow
- Avoid noise sensitive areas
- Lower fuel burn / lower emissions

Simulation Based Design
- Increased productivity
- Faster to EIS with reduced flight testing

Advanced Aircraft Aerodynamics
- Designed for highest efficiency cruise
- Lower drag and fuel consumption
- Testing to validate and optimize aerodynamics
EFFICIENCY IMPROVEMENTS

NEW ENGINES
IMPROVED AERODYNAMICS
CENTER OF GRAVITY MANAGEMENT
NEW WING
WEIGHT SAVINGS

GEX XRS  Global 7000

Fuel burn

-14%*

*Compared with the Global Express XRS on a 6,000 nm mission with 8 pax
CSERIES COMMERCIAL AIRCRAFT FAMILY

Over 95% LRU* Commonality

CSERIES Aircraft Family

CS100
2,950 NM / 110 pax

CS300
2,950 NM / 130 pax

* Line Replaceable Unit
CSERIES AERODYNAMIC DEVELOPMENT

PRINCIPAL TECHNOLOGIES FOR AERODYNAMIC DEVELOPMENT

- Final Design Validation
- Handling Qualities
- Airworthiness Approval
- Design Validation
- Performance Verification
- Aerodynamic Data
- Final Design Validation
- Handling Qualities
- Airworthiness Approval

CFD
- Aircraft Aerodynamic Design
- Power-plant Integration
- Prediction of Lift and Drag
- Aerodynamic Loads

Wind Tunnel Testing
- Design Validation
- Performance Verification
- Aerodynamic Data

Flight Testing
- Final Design Validation
- Handling Qualities
- Airworthiness Approval
Over 4,500 hours of wind-tunnel testing including full scale Reynolds number high-speed testing
Conventional Turbofan
fan speed constrained by low pressure spool
low compressor & low turbine speed constrained by fan
bypass airflow

PurePower® PW1500G Engine
ultra-efficient, light-weight, low-speed fan
low compressor & low turbine speed optimized
bypass airflow

Incremental Improvement
Step-Change Improvement
CSERIES STRUCTURE

ADVANCED STRUCTURAL MATERIALS BRING SIGNIFICANT WEIGHT SAVINGS

Benefits

- Light Weight
- Corrosion Resistant
- Better Maintainability

Advanced Aluminum Fuselage
Advanced Composite
CSERIES ADVANCED COMPOSITE WING
RESIN TRANSFER INFUSION TECHNOLOGY

Winglet. Skins: Carbon fibre
Spars: Carbon fibre

Torque Box.
Spars: Carbon fibre
Ribs: Al Alloy
Skins: Carbon fibre
Access Panels: Carbon fibre

Leading Edge & Slats
Skins: Al Alloy
Ribs: Al Alloy

Aileron
Carbon fibre

Aileron & Spoiler
Hinge Fittings
Al Alloy

Outboard Flap
Carbon fibre

Spoilers (2 ground, 4 multifunction)
Body: Carbon fibre
Fittings: Al Alloy

Inboard Flap
Carbon fibre

Fixed Trailing Edge Shroud
Carbon fibre

MLG Doors
Carbon fibre

MLG attachments
Titanium

Advanced Composites

Standard Materials

Titanium and/or Steel
CSERIES COMPOSITE WING
PRE-PRODUCTION WING TESTED TO ULTIMATE LOAD IN JUNE 2010

From concept design to ultimate load test in 23 months!
C SERIES COCKPIT

- Advanced Fly-by-Wire with Full envelop Protection & Speed Stabilization
- Side Stick Controls
- Cat Illa Autoland
- Five large 15.1” LCD Displays
- Advanced Multi-Scan Weather Radar
- Auto Throttle
- Phase-of-Flight FMS
- Glareshield Tuning
- Electronic Checklist
- Integrated Overhead Panel
- Multifunction Keyboard Panel (MKP)
- Cursor Control Device (CCD)
- Full Format Data Link Printer

Some Available Options:
- CAT Illb Autoland
- Head-Up Display (HUD) System
- Class 2 Electronic Flight Bag
CSERIES 21\textsuperscript{ST} CENTURY COCKPIT

COMPLIANT WITH UPCOMING AIRSPACE REQUIREMENTS

COMMUNICATIONS
- Controller Pilot Data Link Communication (CPDLC) Ready*
- Wireless Data Communications at the Gate*

NAVIGATION
- RNAV/RNP.1
- WAAS Capability
- Systems to Support Runway Safety*

SURVEILLANCE
- ADS-B Out
- Well-Positioned for ADS-B In

SITUATIONAL AWARENESS
- Graphical Weather Information via Data Link*
- Head-Up Display*
- Digital Navigation Charts*
- Electronic Document Management*
APPLYING LIFE CYCLE ANALYSIS (LCA)

CSERIES DESIGN FOR ENVIRONMENT (DFE) ADDS VALUE TO THE PRODUCT

- Integrate green technologies
- Select low impact materials
- Optimize product lifetime
- Minimize end-of-life impact
- Reduce product fuel burn, noise, air emissions and improve operational flexibility
- Eliminate hazardous materials
- Involve Supply Chain in hazardous materials elimination

LCA is an ISO defined process used to assess environmental impacts associated with a product over its life cycle.
CSERIES COMMITMENT FOR THE ENVIRONMENT
AN UNMATCHED ENVIRONMENTAL FOOTPRINT

**CSERIES**

- **20% LESS** CO$_2$
- **50% LESS** NO$_x$
- **4 TIMES QUIETER**

20 EPNdB Margin To Stage 4 = Margin To Upcoming Regulations
**CS300** over a 2,700nm sector, assuming 100% load factor.

**Assuming actual average load factor of 50%**

**Assuming actual average load factor of 25%**

**CSERIES Low Fuel Burn Figures**

- **3.4** litres/100 km
- **4.3** litres/100 km

**2.3** litres/100 km per passenger*
COLLABORATION - AEROSPACE TECHNOLOGY LIFE-CYCLE

- Fundamental Research
- Strategic Technology
- Product development

Avion + Écologique FMP
GARDN
CRIAQ

Push Business opportunities
Pull Technology needs
Pull Program Launch

YEARS

-10 -5 0 +5

TRL

9 8 7 6 5 4 3 2 1

BOMBARDIER PROPRIETARY
Project launched in summer 2010 to improve Camelina for Bio-jet production and verify its performance on a Q400

Team members and roles

- Targeted Growth & Agrisoma - Agriculture company focused on energy crops
- Bombardier/PWC/Porter – ground test and flight on a Q400
- UOP and Sustainable Oils are the leading American companies in the world for processing oils and turning them into a bio-jet

Funded through the Green Aviation Research and Development Network (GARDN)

20% biofuel flights took place with Horizon in Fall 2011

50/50 Flight took place on April 17, 2012 with Porter
Q400 ENGINEERING FLIGHT
1ST BIO-FUEL (D7566) FLIGHT IN CANADA – FEBRUARY 9, 2012

• 2 hrs test flight. No issues, performance as expected
• 1.0% lower fuel flow (lb/hr) in LH engine with 50/50 blend

<table>
<thead>
<tr>
<th>No</th>
<th>Test</th>
<th>Initial Flight Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ground Test - Engine Cold and Hot starts</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>Ground Test - Engine Handling/Acceleration and Deceleration</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>Ground Test - Engine Operation at High Power</td>
<td>N/A</td>
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<tr>
<td>4</td>
<td>Flight Test - Engine Acceleration/Deceleration</td>
<td><a href="mailto:25K@1.23Vs">25K@1.23Vs</a> &amp;Vmo</td>
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<tr>
<td>5</td>
<td>Flight Test - Engine Shutdown and Relight</td>
<td>15K/160kts</td>
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<tr>
<td>6</td>
<td>Flight Test - Approach/Go-Around</td>
<td><a href="mailto:5K@1.23Vs">5K@1.23Vs</a> @ GND, 1.23Vs</td>
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<tr>
<td>7</td>
<td>Flight Test-Single Engine Climb Performance</td>
<td>5K</td>
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<tr>
<td>8</td>
<td>Cruise Performance</td>
<td>5 minute cruise @ 25K &amp; different airspeeds</td>
</tr>
</tbody>
</table>
PORTER FLIGHT – APRIL 17, 2012

1st BIO-FUEL REVENUE FLIGHT IN CANADA

One wing on 50/50 fuel
• 49% Camelina, 1% Carinata

• Hélène V. Gagnon, VP, CSR, Bombardier Aerospace;
• Robert J. Deluce, CEO, Porter Airlines;
• Hon. Glen Murray, Minister of Training, Colleges and Universities, Ontario;
• Sylvain Cofsky, Executive Director, GARDN
CONCLUSIONS

- Bombardier has achieved a position of leader in regional and business aviation through sustained technology development and product innovation;
- Aviation is at a turning point, where high fuel prices and environmental concerns are pushing for new, more efficient aircraft designs;
- Our technology program is aimed at developing aircraft that are more comfortable, less expensive to own and operate, and more respectful of the environment (reduced noise and emissions, recyclable products);
- Our first stake in the ground for the environment is the CSERIES which will bring in 2013 significant gains for the environment;
- In 2016, the Global expanded family will introduce a new level of efficiency for large Business Jets
- We continue to work on promising technologies through partnerships with universities, research centers, suppliers and other partners in industry.