Aircraft Engine Sustainability
Life Cycle Environmental Impact Reduction

Russell Stratton
May 20th 2016
EXPORT CLASSIFICATION

Check if presentation contains no technical data [X] or mark export classification below:

<table>
<thead>
<tr>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Canadian ECL(s):</td>
</tr>
<tr>
<td>2. ECCN(s):</td>
</tr>
<tr>
<td>3. P-ECCN(s):</td>
</tr>
<tr>
<td>4. USML (ITAR):</td>
</tr>
<tr>
<td>5. P-USML:</td>
</tr>
</tbody>
</table>

If unsure of classification, contact the originator of the information or your local BAER. For more details, please view the classification instructions.

PROPRIETARY NOTICE
This document is the property of Pratt & Whitney Canada Corp. (“P&WC”). You may not possess, use, copy or disclose this document or any information in it, for any purpose, including without limitation to design, manufacture, or repair parts, or obtain TCCA, FAA, or other government approval to do so, without P&WC's express written permission. Neither receipt nor possession of this document alone, from any source, constitutes such permission. Possession, use, copying or disclosure by anyone without P&WC's express written permission is not authorized and may result in criminal or civil liability.
A MAJOR CANADIAN EMPLOYER

Corporate headquarters
Engine development, production and aftermarket

Maintenance, Repair & Overhaul

Component manufacturing

Engine production

Engine production
Assembly & test
Flight testing

Engine development and production

Altitude test facility with the National Research Council Canada

GLACIER
Cold weather testing and research facility

Export Classification: no technical data

For planning purposes only
GLOBAL SERVICE NETWORK

- 12,000 operators
- 200 countries and territories
- In more than 52,000 engines in service

Headquarters
P&W Service Centres and P&W Regional Service Centres
Designated overhaul facilities (DOFs)
Customer First Centres (CFirst)
P&W training schools and Flight Safety International
Parts distribution centres

~12,000
In more than 200
Some 52,000

Our product stewardship challenge

Export Classification: no technical data
For planning purposes only
GLOBAL CUSTOMER BASE

30+ major aircraft OEMs

- Bell Helicopter
- Bombardier Aerospace
- Viking Air
- Air Tractor
- Blackhawk Modifications Inc.
- Boeing
- Gulfstream
- Learjet
- MD Helicopters
- One Aviation
- Piper
- Quest Aircraft
- Sikorsky
- Textron Aviation
- Cessna Aircraft
- Beechcraft
- Thrush Aircraft
- Embraer
- Pilatus
- AgustaWestland
- Daher-Socata
- Dassault
- Airbus Group
- Airbus
- Airbus Helicopters
- Airbus Military
- PZL-Okecie
- ATR
- Piaggio
- Aerosud
- Russian Helicopters
- Kazan MIL
- AVIC
- Changhe
- Harbin
- Xi’an
- NAL
- Indonesian Aerospace
- Pacific Aero
- Pacific Aerospace

Export Classification: no technical data

For planning purposes only
EMPOWERING THE FUTURE

Business Aviation

- Cessna Latitude
- Dassault Falcon 8X

Helicopter Market

- S-76D
- EC135 P3

General & Regional Aviation

- AW169
- PT6A-140
- ATR 72

Our sustainable product journey continues…

Export Classification: no technical data

For planning purposes only
THE RISK IMPERATIVE

Long-term Environmental

- Political Instability
- Floods/Mudslides
- Wildfires
- Drought
- Storms Damage
- Dying Coral
- Infrastructure Loss
- Climate Refugees
- Biodiversity
- Glacier Loss
- Famine
- Water Scarcity
- Ecosystem Loss
- Political Instability
- Diseases
- Sea Level Rise

By 2050, Climate Change could cost Canada $21 – $43 billion per year

Product and Operations

- Over 75% of Canadians live in a province with carbon pricing
- Carbon price growth is inevitable
- Customer operating costs (fuel and future carbon offsetting)
- Material price volatility and scarcity risk
- Manufacturing energy intensity and material efficiency

Regulatory Compliance

- NOx Standard
- CO2 Standard
- nvPM Standard


Export Classification: no technical data

For planning purposes only
88% of investors surveyed see sustainability as an opportunity for competitive advantage.

78% as a differentiator in determining industry leaders

91% believe that sustainability should be better embedded into discussions between companies and investors

88% believe that they should pay greater attention to sustainability in company valuations

Source: United Nations Principles for Responsible Investment

Data from over 10,000 mutual funds and 2,800 separately managed accounts over the last seven years indicate: investing in sustainability has usually met and often exceeded the performance of comparable traditional investments, both on an absolute and risk-adjusted basis across asset classes and over time

Source: Morgan Stanley Institute for Sustainable Investing
UTC INFLUENCE / ALIGNMENT

2020 Goals Released to Public

- UTC Continued Commitment
- PWC’s Influence: Continue to Lead; UTC’s “Sustainability Lab”

- Business Operations
- Products
- Suppliers

“The whole future of our company is really going to be based on two things: innovation and sustainability”
– Greg Hayes, UTC CEO (Feb 2016)
OUR 2028 VISION

Fleet Emissions
Significantly reduce our 52,000+ engine fleet impacts

Sustainable Products
Designed, manufactured and serviced to minimize impacts

Zero Waste Sites
All by-products 100% recycled

Carbon Neutral Sites
Only sustainable energy sources

Influence
Be a force for positive change

Be the best aerospace company FOR the world

Export Classification: no technical data
2028 SUSTAINABILITY GOALS
Scope and Relationships

Sustainable Products
- Ecodesign
- Supplier sustainability
- MOCs in product
- Material intensity
- Design recyclability
- Take-back policies

Emissions
- Fleet emissions
- Fleet oil consumption
- Noise
- Alt. energy compatibility

Positive Influence
- Reputation
- Employee engagement
- Suppliers / partners
- Industry leadership
- Community engagement
- Corporate policies

Zero Waste
- Industrial recycling
- Domestic recycling
- MOCs in manufacturing
- Factory water consumption
- Non GHG factory emissions

Carbon Neutral
- Renewable energy
- Energy efficiency
- Operations GHGs

Export Classification: no technical data
For planning purposes only
2028 SUSTAINABILITY GOALS
Scope and Relationships

Sustainable Products
- Ecodesign
- Supplier sustainability
- MOCs in product
- Material intensity
- Design recyclability
- Take-back policies

Emissions
- Fleet emissions
- Fleet oil consumption
- Noise
- Alt. energy compatibility

Zero Waste
- Industrial recycling
- Domestic recycling
- MOCs in manufacturing
- Factory water consumption
- Non GHG factory emissions

Positive Influence
- Reputation
- Employee engagement
- Suppliers / partners
- Industry leadership
- Community engagement
- Corporate policies

Carbon Neutral
- Renewable energy
- Energy efficiency
- Operations GHGs

Export Classification: no technical data
LIFE CYCLE ANALYSIS (LCA)
Methodology

Assesses *environmental impacts from material extraction to end of life*

Can vary in scope (company to product to subcomponent)

Are used to identify the key environmental impacts (hotspots)
Our footprint clearly extends beyond our four walls
FLEET EMISSIONS

- P&WC sees significant future growth in fleet emissions

P&WC fleet emissions reduction strategies include:
- New Product Introduction, Upgrades, Retrofits, Operational Efficiency
  - Operational efficiency: near-term lever to reduce fleet emissions
  - Indirect support: industry adoption of sustainable alternative jet fuels

Export Classification: no technical data
OPERATIONAL EFFICIENCY

Fuel efficiency manuals

Analytics of aftermarket engine health management operational data

• By 2017, help customers identify more efficient operating practices through mission analysis and fuel burn trends

Export Classification: no technical data
Major Portion of Technology Portfolio links to Sustainability:

- Advanced Manufacturing (improved buy-to-fly)
- Improved fuel efficiency
- Materials of Concern elimination (REACH)
- Alternate fuels
- Advanced Combustion Technologies
- Oil Consumption reduction
- Noise reduction technologies
- Thermoplastics vs Thermosets
- Optimized aircraft operational algorithms
- Disruptive Technologies

Export Classification: no technical data

For planning purposes only
LIFE CYCLE ASSESSMENT (LCA)

Company Level

Our footprint clearly extends beyond our four walls

Export Classification: no technical data

For planning purposes only
GHG impact heavily dependant on types and quantities of metals used.

Carbon footprint of different metals depends on how and where they are extracted, prepared, heat treated, and machined.

Impact per pound:

- Material preparation
- Heat treatment
- Part manufacture
- Material extraction

kg CO2 eq. / Lbs

- Aluminium
- Magnesium
- Nickel
- Steel
- Titanium
ECODESIGN – P&WC APPROACH

Through both process and execution

PROCESS

• Sustainable execution requires cascaded accountability down from leadership, to program leaders, to program execution, creating a mandate for day-to-day work

• P&WC is targeting its engineering standard work to build sustainability into our core business activities
ECODESIGN – P&WC APPROACH

Through both **process** and **execution**

**EXECUTION**

- Environmentally focused design requirements

- Building capability and knowledge to explore trade space between eco-design KPI and conventional performance metrics
  - Supporting calculation methods, benchmarking, best-in-class standards
  - Significant potential improvements identified within existing products

---

Export Classification: no technical data

For planning purposes only
Approximately **2.3 million lbs of metal reaches end-of-life each year** in overhaul and retirement of P&WC engines.

### Alloy - Approx. Years Remaining

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Approx. Years Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium</td>
<td>72</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1700</td>
</tr>
<tr>
<td>Aluminum</td>
<td>750</td>
</tr>
<tr>
<td>Nickel</td>
<td>42</td>
</tr>
<tr>
<td>Steel</td>
<td>83</td>
</tr>
<tr>
<td>Copper</td>
<td>36</td>
</tr>
<tr>
<td>Iron</td>
<td>69</td>
</tr>
</tbody>
</table>

- **Price volatility** *(medium term)*
- **Supply stability** *(long term)*

### Materials and Components

#### Waspaloy
- HP disks
- LP disks
- PT disks

#### Titanium
- Blinks
- Fan blades
- Impellers
- Tis shafts
- Diffusers
- HPC Cases

#### Inconel – Nickel - Cobalt
- Cases
- Blades
- Shrouds
- Stators
- Vanes
- C.C liners
- Exhaust

#### Ferrous Metal
- Mg Hsg
- Cases
- LP Shafts
- Stators
- Small parts

---

Export Classification: no technical data

For planning purposes only
Effective End-of-Life management depends on:

- Economics of material recovery and value
- Customer and supplier contracts
BEST PRACTICES AND KEY PROCESSES

WINNING BEST PRACTICES

I. Management Commitment
II. Aggressive Targets & Assignments
III. Embedded Processes & Protocols
IV. Proven & Continuous Return
V. Clear & Consistent Communication
VI. Company Wide Engagement
VII. Dedicated R&D / Innovation

Corporate Strategy
Compelling Vision
R&D
Impact metrics and tracking
Sustainable development structure

Individual Contributors
Employee Performance Reviews
Dedicated resources
SD Champions
Training programs

Business Processes
Budgets
Green process improvement
Supply Chain Management
Standard Work
Design metrics and targets

Making Sustainability Stick – A Worthy Challenge
“When you are being asked to make the business case for sustainability.. perhaps ask them to make the business case for being un-sustainable”

Ray Anderson
1934 - 2011