Industriell Effektivitet
Kista, Stockholm
2013-02-11

Jonas Rosengren
Senior Expert – Propulsion Systems
PPC, Medium Power Propulsion
## Bombardier overview

<table>
<thead>
<tr>
<th></th>
<th>Bombardier Aerospace</th>
<th></th>
<th>Bombardier Transportation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues*</td>
<td>$8.6 billion</td>
<td></td>
<td>Revenues*</td>
<td>$9.8 billion</td>
</tr>
<tr>
<td>Backlog*</td>
<td>$22.0 billion</td>
<td></td>
<td>Backlog*</td>
<td>$31.9 billion</td>
</tr>
<tr>
<td>Employees**</td>
<td>33,600</td>
<td></td>
<td>Employees**</td>
<td>36,200</td>
</tr>
</tbody>
</table>

* As at December 31, 2011  
** As at December 31, 2011. Includes contractual employees.
# A FULL SPECTRUM OF RAILWAY SOLUTIONS

<table>
<thead>
<tr>
<th>Rail Vehicles</th>
<th>Transportation Systems</th>
<th>Services</th>
<th>Rail Control Solutions</th>
<th>Propulsion &amp; Controls</th>
<th>Bogies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light rail vehicles</td>
<td>Monorail systems</td>
<td>Fleet management</td>
<td>Integrated control systems</td>
<td>Traction converters</td>
<td>Portfolio to match entire range of rail vehicles</td>
</tr>
<tr>
<td>Metros</td>
<td>APM systems</td>
<td>Operations &amp; maintenance</td>
<td>Automatic train protection and operation</td>
<td>Auxiliary converters</td>
<td>Full scope of service over the lifetime of a bogie</td>
</tr>
<tr>
<td>Commuter trains</td>
<td>Light rail systems</td>
<td>Material solutions</td>
<td>Interlocking systems</td>
<td>Traction drives</td>
<td></td>
</tr>
<tr>
<td>Regional trains</td>
<td>ART systems</td>
<td>Vehicle refurbishment</td>
<td>Wayside equipment</td>
<td>Control and communication</td>
<td></td>
</tr>
<tr>
<td>Intercity trains</td>
<td>Metro systems</td>
<td>Component reengineering</td>
<td>Services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High speed trains</td>
<td>Intercity systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locomotives</td>
<td>Transit Security</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# PRODUCTS AND SERVICES

<table>
<thead>
<tr>
<th>Light Rail Vehicles</th>
<th>Metros</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="FLEXITY 2" /> (Blackpool, U.K.)</td>
<td><img src="image2" alt="MOVIA" /> (London, U.K.)</td>
</tr>
<tr>
<td><img src="image3" alt="FLEXITY Outlook" /> (Innsbruck, Austria)</td>
<td><img src="image4" alt="MOVIA" /> (Shanghai, China)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Commuter/Regional Trains</th>
<th>Intercity / High-speed Trains / Very high-speed trains</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5" alt="EMU SPACIUM 3.06" /> (Paris, France)</td>
<td><img src="image6" alt="REGINA EMU" /> (Sweden)</td>
</tr>
<tr>
<td><img src="image7" alt="TALENT 2" /> (Germany)</td>
<td><img src="image8" alt="ZEFIRO" /> (China)</td>
</tr>
</tbody>
</table>

*FLEXITY, MOVIA, REGINA, SPACIUM, TALENT, and ZEFIRO are trademarks of Bombardier Inc. or its subsidiaries.*
The Climate is Right for Trains
Megatrends – Climate Change

Challenge
CO₂ emissions are a contributing factor to climate change

Solution
Rail has lower CO₂ emissions than other modes of motorized transport

Source: 2005 CO₂ emission figures in EU-27. EC 2007 and UIC Energy/CO₂ database
The Climate is Right for Trains
Megatrends – Oil Scarcity and Price of Energy

Challenge
Oil becoming scarce and energy prices will continue to be volatile

Solution
Rail consumes dramatically less energy

Energy consumption during operation plus vehicle production

<table>
<thead>
<tr>
<th>Mode</th>
<th>MJ/PASSENGER-KM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Rail</td>
<td>2.1</td>
</tr>
<tr>
<td>Bus</td>
<td>2.8</td>
</tr>
<tr>
<td>Car, Petrol</td>
<td>4.4</td>
</tr>
<tr>
<td>Car, Diesel</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Source: Report DOE/EIA-0484(2008), Release Date: September 2008
“Better urban mobility in developing countries”, IAPT, 2003
Federation of Canadian Municipalities, National Transit Strategy, March 5, 2007
eco⁴ - a Strong Portfolio of Technologies and Solutions

- Energy
- Efficiency
- Economy
- Ecology
Traction Systems supplied by Battery
Drivers for battery technology in traction systems

- Energy saving
  - Storing energy in batteries during electro dynamical braking
- Saving infrastructure investments
  - Operation on battery at the outer non-electrified branch
- Boosting acceleration
  - Evacuating platforms
- Support weak supply systems
  - Smooth and balance current consumption
- Environmental – noise and exhausts
  - Avoiding diesel engine noise and exhausts in station areas
- Safe shunting in depots
  - Running on batteries in depot areas and avoid dangerous supply system, like C20 in Stockholm
UKEMU – The battery technology trial in the UK
Target with the UK EMU battery project

Objectives:
• Test of three different battery technologies
• Demonstrate the ability to operate 20-25 mile without OHL
• Market could prove the battery more economical than infrastructure investment

Project:
• Use an existing AC mode Electrostar, Class 379 (Stansted Express)
• Remove 1/3 of the traction and replace with the battery technology to be tested
• Two routes foreseen for demonstration

Performance:
• Performance comparable with existing diesel trains
• Assuming electrical power 420-840-1260 kW, depending on technology
• Estimated storage of 350-500 kWh
• Needs both high energy transfer AND high specific storage capability
Battery technologies

- Specific energy
- Specific power
- Safety
- Maintenance
- Economy / Expected life time
UK EMU rebuild for batteries
Example of operation of the UK EMU battery project

Performance calculations:
- Three current levels:
  - 2x300A
  - 2x600A
  - 2x900A
Example of operation of the UK EMU battery project

Speed profile created
→ “Full out”
Data used for potential battery suppliers
Example of operation of the UK EMU battery project

Energy consumption vs. Time

Electrical energy calculation to get right dimension of the batteries
Example of operation of the UK EMU battery project

Optimised performance:
- Driving style influences the energy consumption

![Graph showing Speed vs. Distance with two lines: Normal and ECO. The graph compares the speed and distance traveled under normal and eco driving styles.](image)
Example of operation of the UK EMU battery project

Optimised performance:
- Driving style influences the energy consumption
Other projects about to start
Last Mile with the objective:
- Operation for approx 5 min at slow speed
- 30-40 kWh at ~300 kW
Recuperation battery for TRAXX DEME

LOC DEME with the objective:
-Saving fuel by allowing recuperation into battery back
-300-400 kWh at ~1500 kW
Battery Tender

Allows heavy batteries to allow operation on longer non-electrified lines

- 60 ton
- 5-10 MW
- 5-10 MWh
Other opportunities – Example DEMU → DBEMU

Diesel/Battery Multiple Unit with the objective:
-Fuel saving by cycle energy into the battery package

-300 kW
-20-25 kWh/car
-1000kg