The TRAXX Locomotive Platform

Meeting with the Croatian Railways

Janis Vitins
Kassel, April 2, 2007

BOMBARDIER
The EU milestones towards a “rail-liberalized” Europe, … and the Bombardier response

- **15. March 2003**: Opening of cross-border freight on main European freight corridors
  - *BR 185-CH, Re 482, Re 485 for D - CH*

- **01. January 2006**: Opening of international rail freight on the complete EU network
  - *SBB Cargo 484 (on schedule Dec. 04) for CH - I*

- **01. January 2007**: Opening of all rail freight to competitors in the EU, including national services
  - *TRAXX AC & MS for D/A, CH, I, PL, NL, B to Angel Trains Cargo and CB Rail (total 60 MS locomotives)*
  - *TRAXX DE to LNVG and CBRail*
In the late 90’s interoperability became important!→ Railion orders 400 locos BR 185 for 15 & 25 kVAC

- **BR 101**
  - 15 kV catenary (D)
- **BR 145**
- **BR 185.1**
  - 15 kV
  - 25 kV
  - France
  - 9 Countries
- **BR 185.2**
  - 15 kV
  - 25 kV
  - France
  - 9 Countries
  - New IGBT converter
  - „Crash“ capability
  - Modular brake system
The TRAXX Platform of interoperable locomotives is the core business of Division Locomotives

<table>
<thead>
<tr>
<th>Heavy freight</th>
<th>Interoperable locomotives for Cargo, InterRegio and InterCity</th>
</tr>
</thead>
<tbody>
<tr>
<td>IORE Kiruna</td>
<td>TRAXX Platform Locomotives for Europe</td>
</tr>
<tr>
<td>Blue Tiger</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
</tr>
<tr>
<td>140</td>
</tr>
<tr>
<td>speed</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>250–350 km/h</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>High Speed</th>
<th>AVE S102 (330 km/h)</th>
</tr>
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<tbody>
<tr>
<td>AVE S130</td>
<td>(250 km/h)</td>
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> 1040 locos sold, >500 locos in service

* With Patentes Talgo, S.A.
The TRAXX locomotives are available in 4 variants – for the different catenary voltages

<table>
<thead>
<tr>
<th>TRAXX AC</th>
<th>TRAXX DC</th>
<th>TRAXX MS</th>
<th>TRAXX DE</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 + 25 kVAC</td>
<td>3 kVDC</td>
<td>15/25 kVAC &amp; 1.5/3 kVDC</td>
<td>diesel-elektrisch</td>
</tr>
<tr>
<td>Italy, Spain, Poland</td>
<td>Corridors to Benelux, Italy, Poland</td>
<td>Non-electrified lines</td>
<td></td>
</tr>
<tr>
<td>North-South corridors</td>
<td></td>
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TRAXX for cross-border
The TRAXX locos are standard products

<table>
<thead>
<tr>
<th></th>
<th>TRAXX AC</th>
<th>TRAXX MS</th>
<th>TRAXX DC</th>
<th>TRAXX DE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line voltage</td>
<td>15 + 25 kVAC</td>
<td>15 + 25 kVAC + 1.5 + 3 kVDC</td>
<td>3 kVDC</td>
<td>Diesel-electric</td>
</tr>
<tr>
<td>Mass</td>
<td>84 t</td>
<td>85.6 – 88 t</td>
<td>84 t</td>
<td>84 t</td>
</tr>
<tr>
<td>Length</td>
<td></td>
<td>18’900 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td></td>
<td>2'978 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td></td>
<td>4’280 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheel base</td>
<td></td>
<td>2’600 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheel diameter</td>
<td></td>
<td>1’250 / 1170 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power 15 &amp; 25 kVAC</td>
<td>5’600 kW</td>
<td>--</td>
<td>2’200 kW diesel</td>
<td></td>
</tr>
<tr>
<td>Power 3 kVDC</td>
<td>--</td>
<td>5’600 kW</td>
<td>2’200 kW diesel</td>
<td></td>
</tr>
<tr>
<td>Power 1.5 kVDC</td>
<td>--</td>
<td>4’000 kW</td>
<td>--</td>
<td>2’200 kW diesel</td>
</tr>
<tr>
<td>Tractive effort</td>
<td>300 kN</td>
<td></td>
<td>270 kN</td>
<td></td>
</tr>
<tr>
<td>Braking effort</td>
<td>300 kN</td>
<td></td>
<td>150 kN</td>
<td></td>
</tr>
<tr>
<td>Driver’s cab</td>
<td>air-conditionning &amp; pressurization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>140 / 160 / 200 km/h</td>
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The idea of „commonality“ is taken from the airline industry. The features of a common fleet allow the operators to reduce costs.

- **Efficiency improvements**
  ... same as CRJ & Airbus A 319, 320, 321

- **Cost reductions in various areas** ...
  - Training
    (loco driver, personnel of depots and workshops)
  - Spare parts & logistics of procurement
  - Investments in depots & workshops
  - Documentation
  - Engineering
  - Reliability & availability

→ **Total savings of SBB Cargo: 435 kEuro/loco**
  - NPV over 20 years for the TRAXX MS
TRAXX passenger locomotives

- LNVG electric & diesel
- Veolia (Connex)
- E 464 Trenitalia
- Cisalpino
- CFL, Luxembourg
- DB Regio
Bombardier is the largest supplier of 3 kVDC locomotives

- Trenitalia E 412
- Trenitalia E 405
- SBB Cargo Re 484
- Rail Traction Company EU 43
- Trenitalia E 464
Recent new orders of Bombardier locomotives …

- **Angel Trains Cargo**: TRAXX F140 MS for D/A-CH-I-NL (10), D/A-NL-B (15), D/A-PL (10) & TRAXX F140 DC (10) for Italy

- **LNVG**: 11 Locos TRAXX P160 DE

- **CB Rail**: 25 Locos TRAXX F140 MS for D/A-CH-I (10), D/A-NL-B (5) & D/A-PL (10) and 10 Loks TRAXX F140 DE

- **Renfe Mercancías**: 100 Locos TRAXX F140 DC for Spain 3 kVDC

- **“Hector Rail”**: 10+ Locos TRAXX F140 AC for corridor Germany – Denmark – Sweden with options D – S.


**And also …**

- **Trenitalia Regio**: +150 units E 464 (total 538 units)

- **Renfe**: 90 powerheads for multi-system (3 kVDC + 25 kVAC)
The TRAXX F140 DC (S 253) of the Spanish Renfe Mercancías

Locomotives sold: 100 units
Catenary: 3kV DC
Speed: 140 km/h
Power: 5,4 MW
Gauge: 1668 mm (Iberian gauge)
14 years maintenance contract
Delivery: 2nd half 2008 - 2010

Renfe S 253
Bombardier sold 6 TRAXX F140 AC to Hector Rail for the corridor D-DK-S

Catenary: 15 kV & 25 kV AC
Speed: 140 km/h
Power: 5,6 MW
Delivery: 01/2008 – 04/2008
Railway liberalization in Europe leads to new locomotives

- **Locomotives for cross-border services**
  - New components, systems and international homologation procedures are needed

- **High performance at lower cost**
  - Standard products with large economies of scale

- **Lower operating costs**
  - New technologies

- **Short delivery schedules and small delivery series**
  - “Off the shelf” locomotives, with a high degree of standardization

- **High reliability and availability**
  - Proven products, components and systems

- **Service support in all countries**
  - Bombardier presence in different countries. Efficient spare parts provision from the TRAXX Platform
The TRAXX Platform is modular – in three dimensions

**Networks**

- **AC** (15 & 25 kVAC)
- **DC** (1.5 & 3 kVDC)
- **MS** (AC & DC)
- **Diesel**

**Speed**

- **Cargo** 140 km/h
- **InterRegio** 160 km/h
- **InterCity** 200 km/h

**Country homologations**

- D
- CH
- F
- L
- A
- DK
- S
- N
- HU
- I
- NL
- B
- HR

**Propulsion systems**

- GSM, GPS

**Catenaries**

- Additions

**Country packages**

- Joint basis

**Country homologations**

**Speed**
The four types of TRAXX locomotives match the needs of the various countries and cross-border corridors

TRAXX AC (15 + 25 kVAC)
- Germany / Austria
- Cross-border services to CH, L, F, DK, S, N as well as Central & Eastern Europe

TRAXX MS (15 + 25 kVAC & 1.5 + 3 kVDC)
- Cross-border services to Poland, Benelux, Italy, France, …

TRAXX DC (1.5 + 3 kVDC)
- Italy, Poland, Spain

TRAXX DE (diesel-electric)
- All non-electrified routes
The TRAXX locomotives are successful on western EU freight corridors, including Regio passenger services.

SBB Cargo Re 482
CH - D

SBB Cargo Re 484
CH - I

Railion BR 185
D - F

E 186
D, NL, B, A, PL, CH, I

Homologation available
Homologation in existing contracts
Homologation planned
AC and MS locos are needed for cross-border traffic between Germany and neighboring countries.
TRAXX AC are used by SBB Cargo, BLS Cargo and Private operators for traffic from Germany to the border of Italy.
The TRAX AC2 – DACH operate cross-border in three countries: Germany, Switzerland and Italy.

The TRAXX AC2 – DACH operates N - S and E – W:
- Germany – Switzerland
- Germany – Austria (Vienna, Brenner)
- Switzerland – Austria

Re 482 on the Brenner Pass
The TRAXX AC are used by Railion and Mitsui for operation between Germany and northern France

- The BR 185 (20 Locos) are in revenue service since Dec. 2003 between Mannheim – Metz
- Mitsui has 7 locomotives which can operate on both sides of the Rhine to Basel Muttenz
The CFL Class 4000 locomotives can operate on 15 + 25 kVAC and in 4 countries (L, D, B, F)

- The CFL Class 4000 is a TRAXX AC locomotive for 140 km/h with passenger information systems
- It is used for passenger and freight trains
- The Class 4000 can be upgraded to ETCS (ETCS L1 deployment in L)
The TRAXX locomotives are now operating on Corridor #4, D – A – HU. Operator in Hungary is Floyd.

- This opens new opportunities for freight between D and the EEU countries (HU, RO, HR, YU, BG and Turkey.
- These countries are „easy“ to access with 25 kVAC and Indusi
- Private operators are more innovative and have a high potential for future traffic
With the TRAXX locos Re 482 & 484, SBB Cargo becomes a major freight operator between Germany and Italy.

- In total more than 150 TRAXX locos operate north–south between Germany and the Italian border.

North-Locomotive
Re 482
cross-border between D - CH

South-Locomotive
Re 484
cross-border between CH - I
Interoperability with TRAXX locomotives on all important European corridors – examples in delivery

Total: 68 TRAXX MS ordered:
- Angel Trains Cargo
  - 35 Locos
- CBRail
  - 25 Locos
Starting mid 2007 the TRAXX locomotives will operate to the Rotterdam harbors over conventional lines as well as on the Betuweroute and the HSL Zuid with ETCS L2.

Locomotives for Angel Trains Cargo and CBRail
- Bombardier type: TRAXX MS
- Homologation: Bombardier
- Countries (variant 1): D/A-NL-B
- Countries (variant 2): D/A-CH-I-NL
- Begin operations: Mid 2007

30 MS locomotives sold for operation between Germany and the Netherlands.
The TRAXX MS locomotive Re 484 was first to operate on the Betuweroute on 25 kVAC (26. Aug. 2006)
The new TRAXX MS (D/A-PL) locomotive hauling a 3’340 ton train load, length 570m, in Poland.
The catenary voltages and the train safety systems are critical and have a high impact on costs

- 5 major line voltages
- 8 different catenaries
- ca. 25 different ATP systems
- 4 different loading gauges
Today, the largest challenge is to fit the different national train safety systems into the locomotives and to homologate the locomotives in the various countries. Integrated solutions are necessary and a migration to ETCS must be possible.
The Bombardier driver’s desk allows the complete integration of national train safety systems
Since January 2004 the TRAXX locomotives are equipped with LZB & PZB as STMs – for interoperability.

- The interface to the locomotive is via MVB (UIC, IEC norm)
- The interface to the ETCS (EVC) is via MVB / Profibus

→ **STM based ETCS systems are advantageous even if there is no initial requirement of ETCS L1 or 2!**
Traffic is expected to increase on Corridor # 4 (Asia – Europe) → TRAXX AC into Eastern Europe

- The line voltage is 15 + 25 kVAC. → TRAXX AC is the best fit
- The TRAXX F140 AC can operate in all Eastern Europe with catenaries 15 & 25 kVAC
- The ATP systems needed are Indusi & EVM(HU)
- Migration to ETCS must be possible
The integration of the ATP systems based on RCS equipment (ETCS & STM) is key.

Loco E 186 for the corridor NL-D-A-CH-I

The diagram illustrates the integration of the ATP systems, including ETCS and STM, with redundant displays and a vehicle data bus (MVB). The systems are deployed across Italy, Switzerland, Germany, Austria, and the Netherlands, including Betuweroute. Bombardier's SCMT MMI and I/O, GW components are also shown.
ETCS Level 2 installations on TRAXX Locomotives

Switzerland – NBS (Rothrist-Mattstetten) and Lötschberg base tunnel

- BLS Cargo: 20 locomotives Re 485
- Railion: 10 locomotives BR 185-CH
- SBB Cargo: 10 locomotives Re 484
- Standard: SRS 2.3.0 (with specific CH „change requests“)
- Financing: BAV

Betuweroute (Netherlands)

- Angel Trains Cargo: 10 Locos D/A-CH-I-NL & 15 Locos D/A-NL-B
- CB Rail: 10 Locos D/A-NL-B

HSL Zuid (Netherlands and Belgium)

- Angel Trains Cargo: 15 Locos D/A-NL-B

In addition (Spain)

- High speed powerheads: AVE S 102 and AVE S 130
The locomotive related costs (including service & maintenance) are in the range of 13 – 24% of all costs.

Apart from the administrative and operating costs, the following cost elements are dominant:

- Energy (ca. 22%), track access (ca. 20%) and loco fix costs incl. service and maintenance (13 – 23%)
What can we do to lower total train costs?

- **Operations costs → This is a question to the Railways**
  - Industrialization of transportation, e.g. ski-lift

- **Energy costs (today measured in D, NL)**
  - Improve locomotive efficiency, including maximum regeneration at braking!
  - Avoid “stop - and - go” operation with “good” slots.
  - Driver training. 20% reduction of energy consumption can reduce total train costs by 4%!
  - Lobby for direct energy measurement in all countries(?)

- **Locomotive fix costs**
  - Use identical locomotives, e.g. BR 185-CH, Re 482, Re 485
  - Reduce maintenance costs, e.g. “Airbus model”, consignment stock
New locomotives pull long & heavy train loads
The Flexifloat bogie has high performance and provides long wheel life and low track forces.

- High tractive effort of 300 kN
- Surplus tractive effort for acceleration on grades
- 5.6 MW at the wheel
- Effective adhesion control
- High secondary springs
- Push/pull rod
- Short axle base, 2.6 m

- Low track forces $\Rightarrow$ long wheel life
- Low load transfer $\Rightarrow$ high Adhesion
- Large wheels, $\varnothing$ 1250mm $\Rightarrow$ low LCC
- Robust & simple frame $\Rightarrow$ low LCC
- High running comfort $\Rightarrow$ driver comfort
- Low noise $\Rightarrow$ low environmental impact
The Flexifloat bogie has a very good adhesion capability and permits heavy train loads

- Push/pull rod with a virtual extension to track level in the middle of the bogie. Load transfer is very low.
- Adhesion control system which cleans the wheels and tracks through a controlled slip. In this way the tractive effort increases from wheel 1 to wheel 4 (TE1<TE2<TE3<TE4)
- Free wheelset movement which avoids lateral sliding of the wheels
- Short axle base which avoids lateral sliding of the wheels in curves

\[ \text{Slip} = \Delta V_1 = V_1 - V_0 \]
The effect of “track cleaning” is verified by measurements with heavy train loads on wet tracks.

- The locomotive can put 300 kN consistently onto the track.
- The leading bogie operates at a larger slip and “cleans” the track.
- Due to the cleaning the following bogie has a higher tractive effort.

Test conditions:

- Starting from standstill in 16 ‰ in double traction
- Total train load: 3340 tons
- Weather: natural wet tracks

Leading loco
The bogies are interchangeable – with the same interfaces for 140, 160 and 200 km/h

The same loco for:
- Cargo
- Regio
- Intercity

And services:
- national
- international
Push-pull operations have been verified in extensive tests in Switzerland by SBB and DB Systemtechnik in 2003

- Measurements on TRAXX locos on Gotthard and Lötschberg with curve radius of down to 250m.
- Measurement of wheel forces on locomotive and wagon (Sggns empty) with respect to safety.
- Tests with standard buffer plates and with Nylatron

**Result:** The TRAXX locos can push the same train loads as the SBB Re 460; no need of Nylatron

TRAXX and Re 460 locomotives are certified for the same train loads.
In collaboration with DB and SBB, Bombardier has obtained a large experience in push-pull operation

SBB Re 460 with IC 2000 presently at 160 km/h
- with WTB (wire train bus) train communication

BR 101 are used primarily in push-pull for speeds of 200 km/h throughout Germany
- with German ZMS (Zeit-Multiplex Steuerung)

The BR 146 is used extensively in push-pull operation with DD coaches throughout Germany
- with German ZMS (Zeit-Multiplex Steuerung)
The TRAXX locomotives provide much improved protection to the driver and have lower repair costs.
Crash test in Poland at CNTK
The TRAXX fulfill the upcoming TSI, prEN 15227

Very limited crash capability

Controlled energy absorption

- Severe damage of the carbody leads to very high repair costs
- TRAXX: Controlled deformation of the front part only

Compared to conventional locomotives …

- much improved passive safety to the loco personnel
- much reduced repair costs
The layout of the TRAXX Platform allows to produce electric & diesel variants. The propulsion system is variable.

The propulsion system is modular, for AC, MS, DC & DE.
The TRAXX locomotives one carbody for all types, diesel and electric locos
The PowerPackages of the electric and diesel TRAXX locomotives have identical interfaces into the locomotive.
The diesel locomotive contract to LNVG

4th contract in Oct. 05
- 11 locos TRAXX P160 DE
- Fleet maintenance for 15 years
- Deliveries starting Aug. 2007
- Begin of operations in Dec. 2007

The LNVG electric and diesel locomotives have a high degree of commonality, e.g. the same bogies, incl. traction motors and drive systems
The TRAXX F 140 DE / P 160 DE performance data

- Max. speed: 140 / 160 km/h
- Versions: Cargo / passenger
- Loading gauge: UIC 505-1
- Power diesel engine: 2200 kW
- Power at the wheel: 1845 kW
- Length: 18900 mm
- Starting tractive effort: 270 kN
- Braking effort: 150 kN
- Mass (Passenger): 84 t
- Mass (Cargo): 83 t
- Wheel diameter: 1250 / 1170 mm
- Dynamic brake: 1600 kW
- Fuel tank: 4000 liters

The TRAXX DE provide the maximum possible power for a 4-axle loco with 21t axle load
As standard products, TRAXX Locomotives have proven high reliability and availability.

**BR 185 Reliability**

- The reliability is >> 380‘000 km (Contract)

**BR 185 Availability**

- The availability is > 97% (Contract)

*) Gemittelte Laufleistung zwischen Ausfällen mit Bedarf einer Hilfslokomotive
TRAXX: New technologies

Mobile MMI – Maintenance Improvement

- All diagnostic data online via Wireless LAN
- Interactive failure localization with „navigation“, circuit diagrams, repair instructions, reports etc.
- Integration of component pictures and action sequences possible

Oil free piston compressor

- Less maintenance
  - no oil filter elements
  - no oil refill
  - no disposal of contaminated liquids
- Directly accessible in the underframe
- Integrated air dryer unit
Remote radio access lowers operating costs and improves operational logistics.

The TRAXX platform is equipped with GPS & GSM remote radio diagnosis.
The TRAXX Platform contributes to reducing operating costs and to increasing competitiveness

- The operator has a choice of four standard locomotive types based on the same technology for the networks: AC, DC, MS, Diesel
  - Reduction of fleet variants
  - Same MMI and operating modus
  - Same technical performance
  - Lower investment costs

- **Cost reduction by means of commonality** (similar to Airbus 319, 320, 321)
  - Same spare parts
  - Low need of training rapid fleet introduction
  - Reduced investments in depots and workshops

- **High reliability and availability**
  - Achieved by service proven components and systems

- **Short delivery schedules**
  - Obtained by standardized production processes and established sub-suppliers
The TRAXX Platform provides HZ with a choice of traction.