



MODERNE SCHIENENFAHRZEUGE GRAZ 2014, SEPTEMBER 8TH

Die ZEFIRO Familie – Eine neue Dimension der Hochgeschwindigkeit

*The ZEFIRO family – a new
dimension of high-speed*

Dr. Alexander Orellano
Director, Vehicle Engineering

Lars Harnack
Chief Architect ZEFIRO
Vehicle Engineering

BOMBARDIER VERY HIGH SPEED & HIGH SPEED TRAINS

Over 1,000 trains in operation worldwide



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ZEFIRO trains product range

The *ZEFIRO* products cover a wide range of VHS solutions for various markets and customers in the world:

ZEFIRO products

ZEFIRO250

- Coaches
- Sleeper
- 8 car train
- 16 car train

V300ZEFIRO*

- UIC coaches
- 8 car train

* In cooperation with AnsaldoBreda for selected markets.

ZEFIRO380

- Wide carbody coaches
- 8 car train

250 km/h

300 - 360 km/h

380 km/h

ZEFIRO – a new sense of very high speed

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the evolution of mobility

Innovations developed within “Gröna Tåget” Green Train R&D program for highspeed train in Sweden



REGINA X55
Interiors



ZEFIRO China
Aerodynamic
optimization



OMNEO SNCF PH
Permanent
Magnet motor

TWINDEXX SBB
PM-motor, ALS



V300ZEFIRO
Trenitalia
ALS, EBI Drive



REGINA : ERTMS



Regina Gröna Tåget test train





ZEFIRO 250

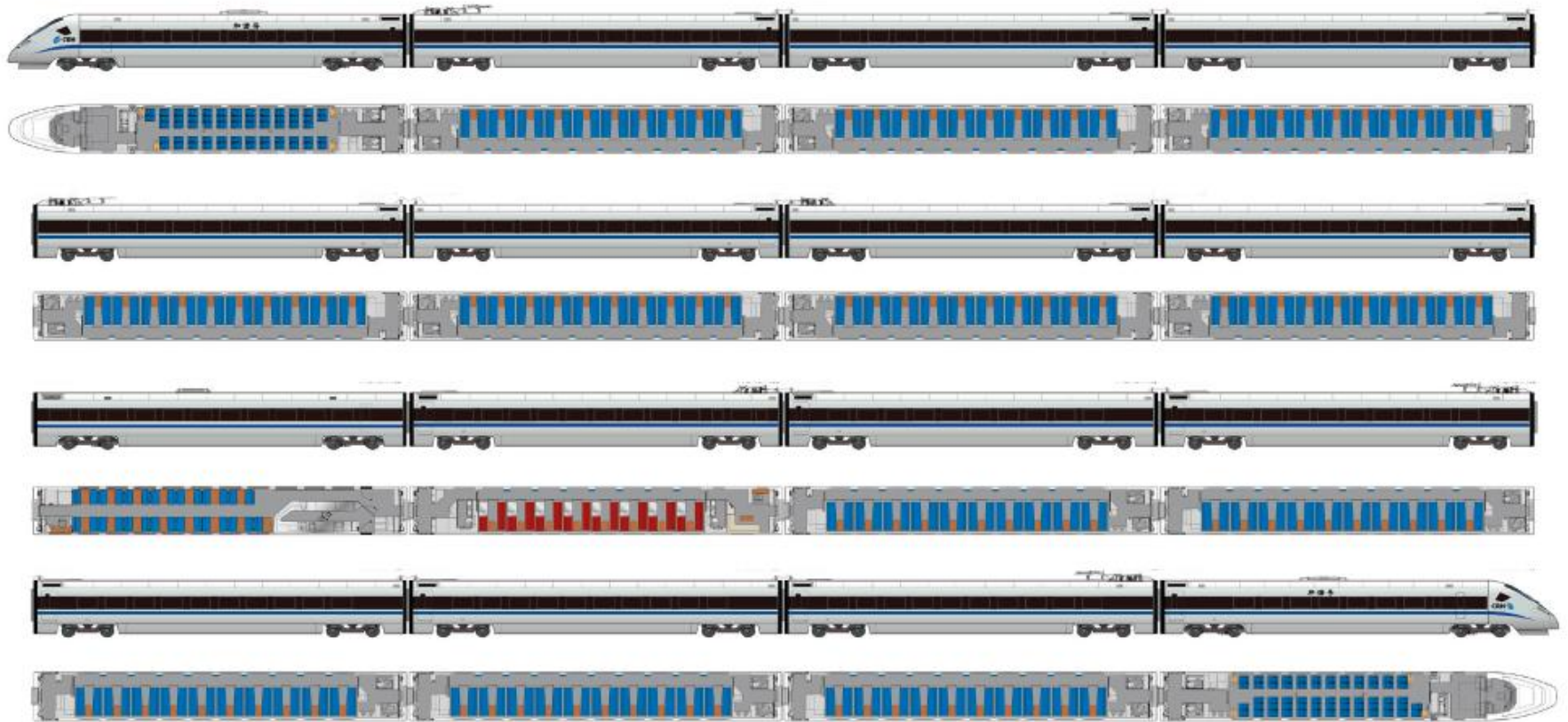
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ZEFIRO 250 coach / sleeper – Technical Data

Parameter	Values
Service speed range	250 km/h
Variants	Sleeper or seater coaches, 8 or 16 car non articulated trainsets
Capacity range	Sleeper 16 car configuration: 122 seats, 480 beds, 16 luxury beds
Train length	429 m (16 car), 216 m (8 car)
Carbody	Stainless steel carbody in wide profile
Voltage	25 kV AC,
Propulsion	<ul style="list-style-type: none">■ Asynchronous motors, forced cooling,■ Distributed drives (63% motorization)■ 13.5 MW
Multiple operation	No for 16 car trainset, yes for two 8 car trainsets
Starting acceleration	> 0,6 m/s ²
Service train weight	859 t (16 car trainset)
Axle load	16,5 t
Bogie	Regina type with 2,7 m wheelbase

ZEFIRO 250 Sleeper – Layout



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ZEFIRO 250 Sleeper – Exterior Design



ZEFIRO 250NG – Technical Data

Parameter	Values
Service speed range	250 km/h
Variants	8-car non articulated train sets
Capacity range	Seating Capacity 613 (1st class: 48, 2nd class: 565)
Train length	208.940 mm
Carbody	Aluminium carbody in wide profile
Voltage	25 kV AC
Propulsion	<ul style="list-style-type: none">■ Asynchronous motors, forced cooling,■ Distributed drives (63% motorization)■ 5.5 MW
Multiple operation	Yes
Starting acceleration	> 0,6 m/s ²
Service train weight	428 t
Axle load	16,5 t
Bogie	Regina type with 2,7 m wheelbase

ZEFIRO 250NG – Layout of CRH1-NG

Car #1 (1st class coach) 48

Car #2 (2nd Class Coach) 90



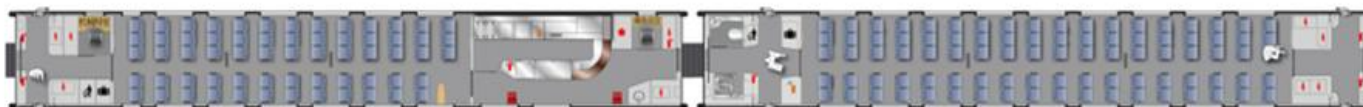
Car #3 (2nd Class Coach) 90

Car #4 (2nd Class Coach) 77



Car #5 (2nd Class Coach/Dining) 63

Car #6 (2nd Class Coach) 90



Car #7 (2nd Class Coach) 90

Car #8 (2nd Class Coach) 65



total: 613 (1st class 48; 2nd class 565)

car	1	2	3	4	5	6	7	8
Seat per car	48	90	90	77	63	90	90	65



ZEFIRO 250NG – Exterior Design



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V300ZEFIRO

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VHS 2.0 – The next step ahead for Europe



V300ZEFIRO was selected by Trenitalia as the new ETR 1000 for Italy

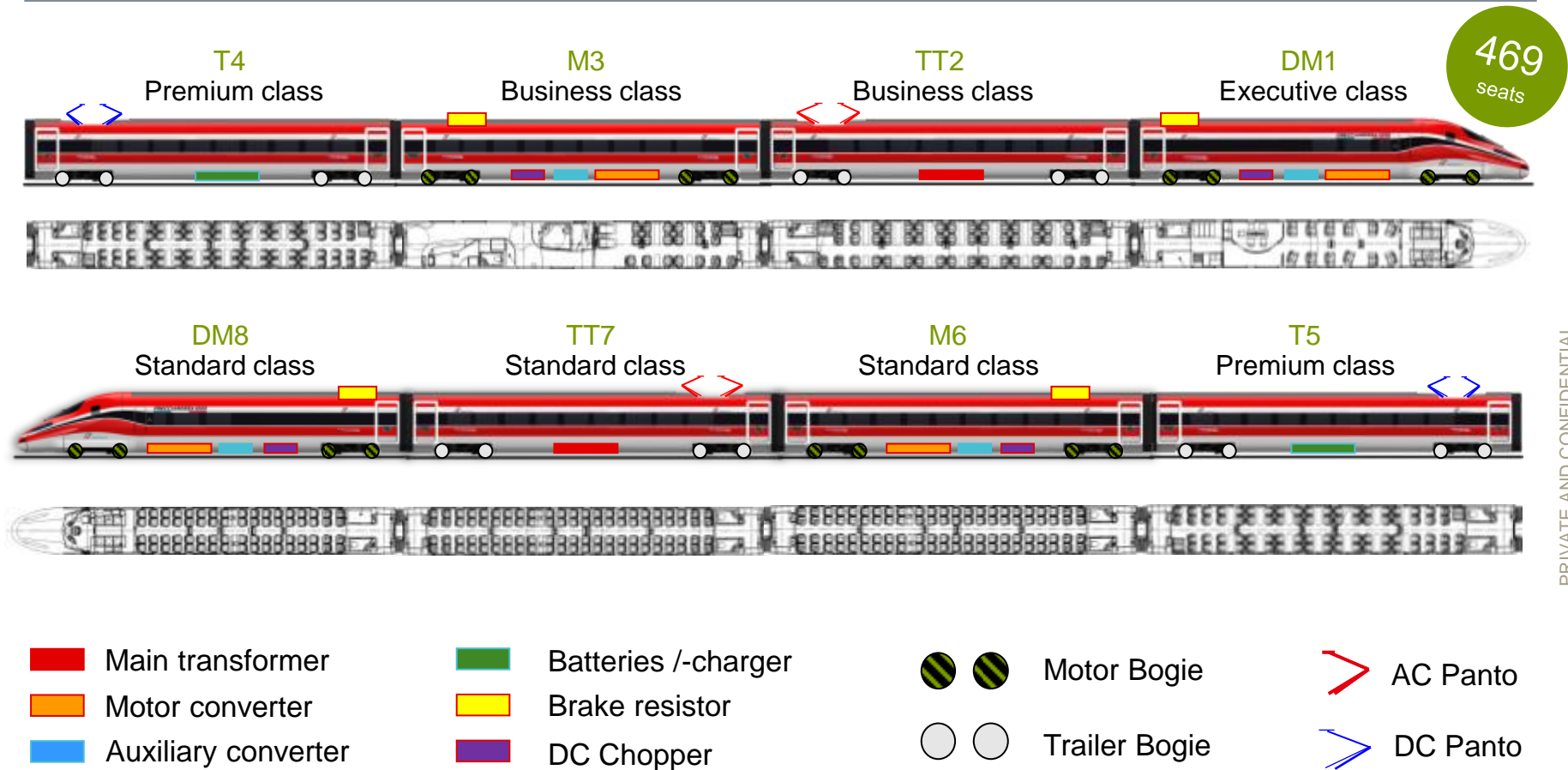
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V300ZEFIRO – Technical Data

Parameter	Values
Service speed range	25kV: 360 km/h / 3kV DC: 300 km/h
N° of cars / train length	8-car train set / 202.000 mm
Capacity range	469 seats + 2 PRM places per train
Voltage	25 kV AC & 3 kV DC (designed for optional: 15 kV AC; 1.5 kV DC)
Propulsion	Single axle drive with 50% motorized axles – 9,8 MW rail power
Starting acceleration	> 0,7 m/s ²
Multiple operation	yes
Carbody	Aluminium car body, UIC profile 505.1, 13 + 1 PRM doors per side
Car length	End car: 26.300 mm / trailer car: 24.900 mm
Car height / width / floor level	4.080 mm / 2.924 mm / 1.240 mm
TSI compliance	Compliance with all new international and national standards
Bogie	Bombardier FLEXX speed with 2,85 m wheelbase

V300ZEFIRO – Train architecture



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The V300ZEFIRO VHS trains can be ordered in various configurations.
Selected for Italy: 8-car configuration with multisystem AC / DC traction

V300ZEFIRO – Exterior Design ETR 1000

The V300ZEFIRO trains are optimized for drag and side wind stability



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V300ZEFIRO – Modular driver's desk design



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V300ZEFIRO – Interior design example



The V300Zefiro provides a wide range of flexible interior solutions such as: Different seating setups for various class layouts, bistro or full restaurant, state-of-the-art multimedia system and full compliance with PRM standards

FRECCIAROSSA 1000 – INTEROPERABILITY ACROSS EUROPE

Bombardier's extensive experience, the necessary know-how and relations with European homologation bodies and processes in almost all countries will make the *Frecciarossa 1000* on the following EU corridors (incl. national ATC systems and ETCS 1&2):

	25 kV AC	15 kV AC	3 kV DC	1.5 kV DC
Italy-France				
Italy-Swiss-Germany				
Italy-Austria-Germany				
Italy-Swiss-Austria-Germany				
Italy-France-Spain				
France-Benelux-Germany				
Italy-France-Belgium				
National versions				

Mock-up road show in Italy



Roll-out and first test runs





ZEFIRO380 China

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Launch of Bombardier's first own very high speed product

Key project data

Nr. of trains:	70 (8 car trains)*
Nr. of cars:	560
Pre-NTP:	01 April 2009
NTP:	29 September 2009
Start trial run:	December 2013
Delivery of first train:	December 2014

* Originally 20 8-car trains and 60 16-car trains, changed on 05.September 2012 to have in addition 46 Zefiro250 and 60 Zefiro250NG-trains

Partnership with our Chinese joint venture BST

85% of production to be localized

BT: Engineering, testing, ToT, PI

BST: Engineering, production, homologation, PI

***ZEFIRO380* China – A new VHS train generation for China**

Bombardier has designed for China a new generation of very high speed trains which is based on our rich expertise in VHS products.

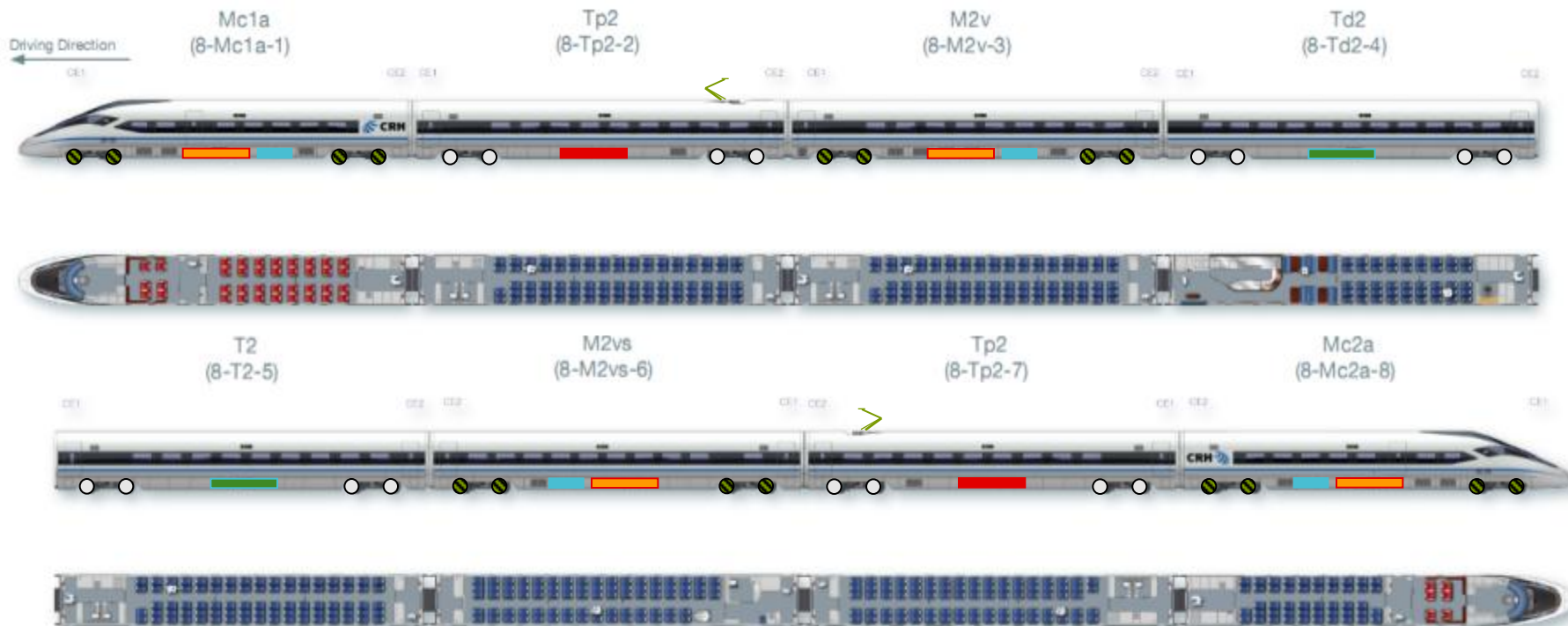
- In October 2009, BST has received an order for a new generation of VHS trains for China for the delivery of 70 8-car train sets (Originally 20 8-car and 60 16-car train sets, changed in September 2012 to have in addition 46 Zefiro250 and 60 Zefiro250NG-trains).
- The CRH380D (*ZEFIRO380* China) in all aspects is truly designed and built for an operating speed up to 380 km/h.
- Many innovations are incorporated into the design, e.g.:
 - Very aeroefficient train shape including new systems like circumferential fairing for inter-car section
 - Fully encapsulated high voltage components, no protruding elements on the roof and fully closed inter car gaps
 - New generation of VHS bogies
 - Optimized propulsion components



ZEFIRO380 China – Technical Data

Parameter	Values
Service speed	Up to 380 km/h; test speed up to 420 km/h
Variant	8-car non articulated train sets
Capacity range	569 seats (up to 664 seats possible)
Train length	215.300 mm
Car width	3.358 mm
Carbody	Aluminium car body, wide profile, 1 or 2 doors per side
Voltage	25 kV AC
Propulsion	<ul style="list-style-type: none">• Asynchronous motors, forced air cooling• Distributed drives (50% motorization)• 10 MW
Multiple operation	Yes
Starting acceleration	> 0,48 m/s ²
Service train weight	458 t
Axle load (TSI)	Max. 17 t
Bogie	FLEXX speed with 2,7 m wheelbase

ZEFIRO380 China – Train architecture



Car type	Mc1a	Tp2	M2v	Td2	T2	M2vs	Tp2	Mc2a	Train
1 st class	38							6	44
2 nd class		84	84	45	84	81	84	48	510
Bistro				14					14
Wheelchair						1			1
Total	38	84	84	59	84	82	84	54	569

 Main transformer

 Motor converter

 Auxiliary converter

 Batteries /-charger

 Motor bogie

 Trailer bogie

 Pantograph

The Exterior Design *ZEFIRO*380 China

The *ZEFIRO* trains are going to set a new standard with a strong and powerful design



Interior Design according customer requests



Business (VIP) class



1st class



Interior Design according customer requests



Restaurant

2nd class



Preparation of Production

Production of some Mock-ups, e.g. segments of car body shell, complete Mc-car body, interior and cab

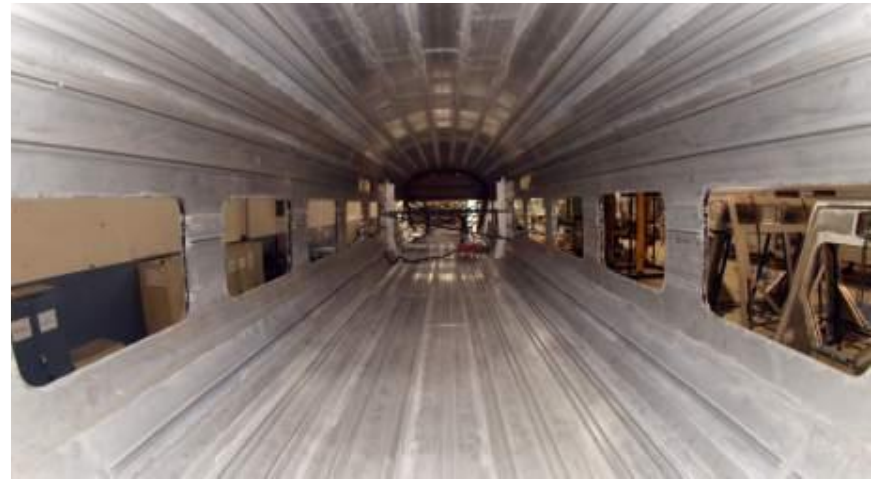


BST, May 2010



Innotrans 2010

ZEFIRO380 China – The front-car mock-up in Hennigsdorf



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Car body production in BST



Final assembly

Start final assembly: 2010-12-31 (delivery of 1st car body)



Testing

The testing of the new train include:

- ✓ Component & system tests
- ✓ Iron Bird tests
- ✓ Roller rig in Chengdu
- ✓ Climate chamber tests in Qingdao
- ✓ Static Tests
- ✓ Up to 50 km/h on Sifang test loop in Qingdao
- ✓ Up to 160 km/h on Beijing test loop
- ✓ Highspeed tests on Mainline: 2012/13
- ❑ 600.000 km test: started Dec.2013

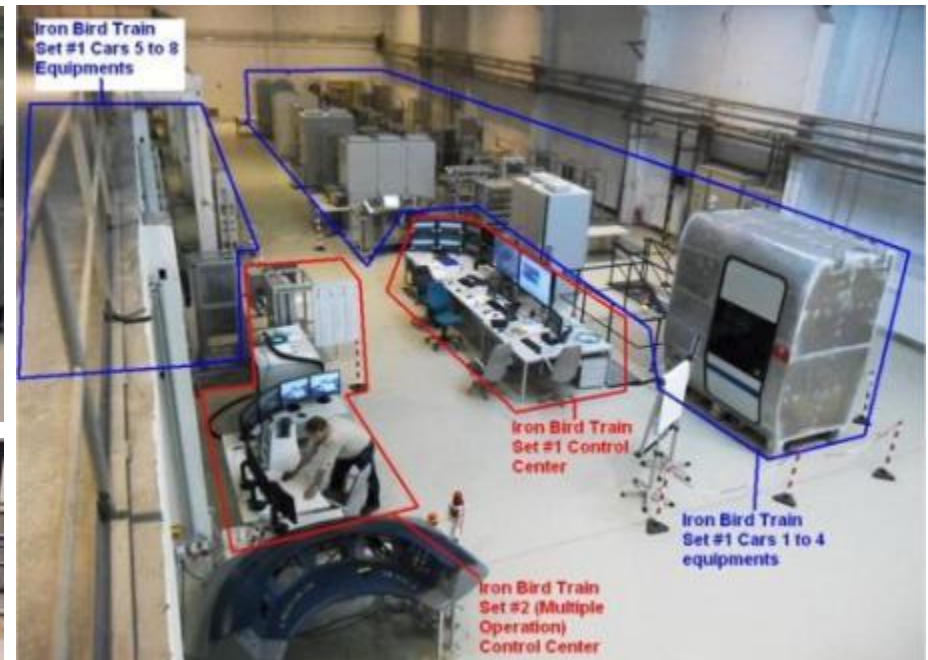
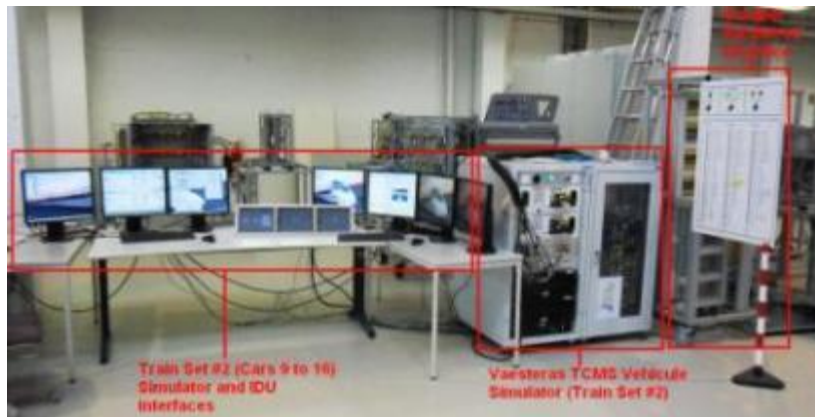


Iron Bird train test platform

Thanks to Iron Bird, all train tests are done in advance of the manufacturing and testing of serial train production in order to shorten the test phase and reduce the impact of re-design

TCMS software simulators including multiple operation with “software train” or hardware test platform “Iron Bird”

“Iron Bird” 8-car train connecting the actual train systems, e.g. door and brake systems, including the wiring, bus systems, and power supplies



Passenger service since April 18th, 2014



AERODYNAMIC RESISTANCE – MOTIVATION

$$P_{\text{power traction}} = (c_w * A * \rho / 2) * v^3 + (m * a) * v$$

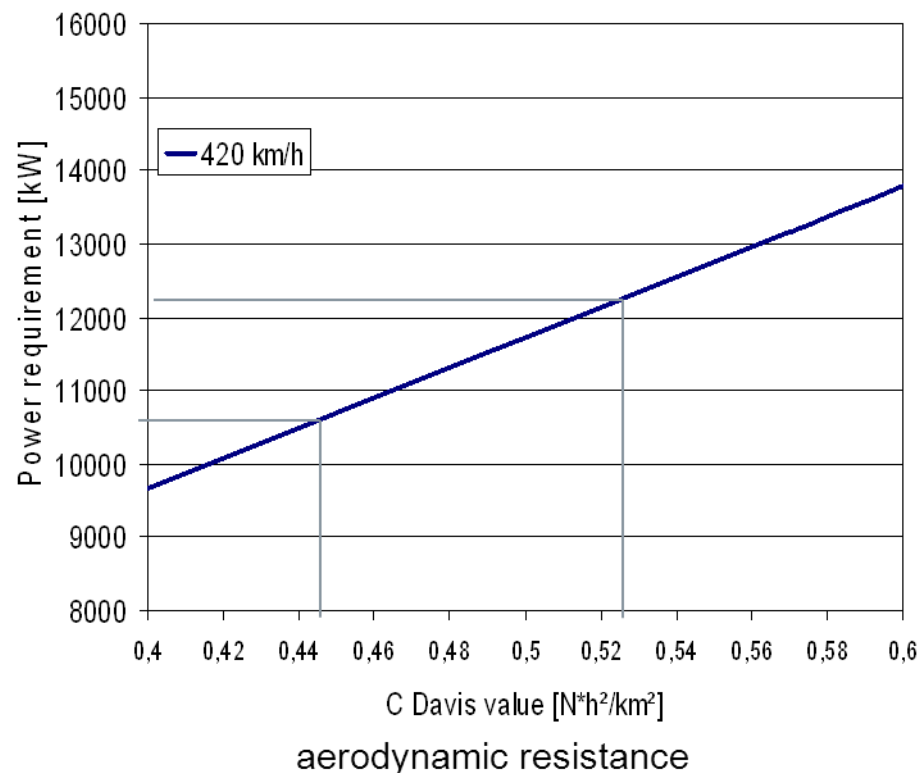
c_w	aerodynamic resistance
A	reference area (10m ²)
ρ	air density [kg/m ³]
v	train velocity [m/s]
m	mass of train kg]
a	acceleration [m/s ²]

Installed Power

- Traction power is a function of the aerodynamic resistance
- Traction power for a train should be as low as possible to reduce one off and LCC costs, weight and complexity

Energy Consumption – traction

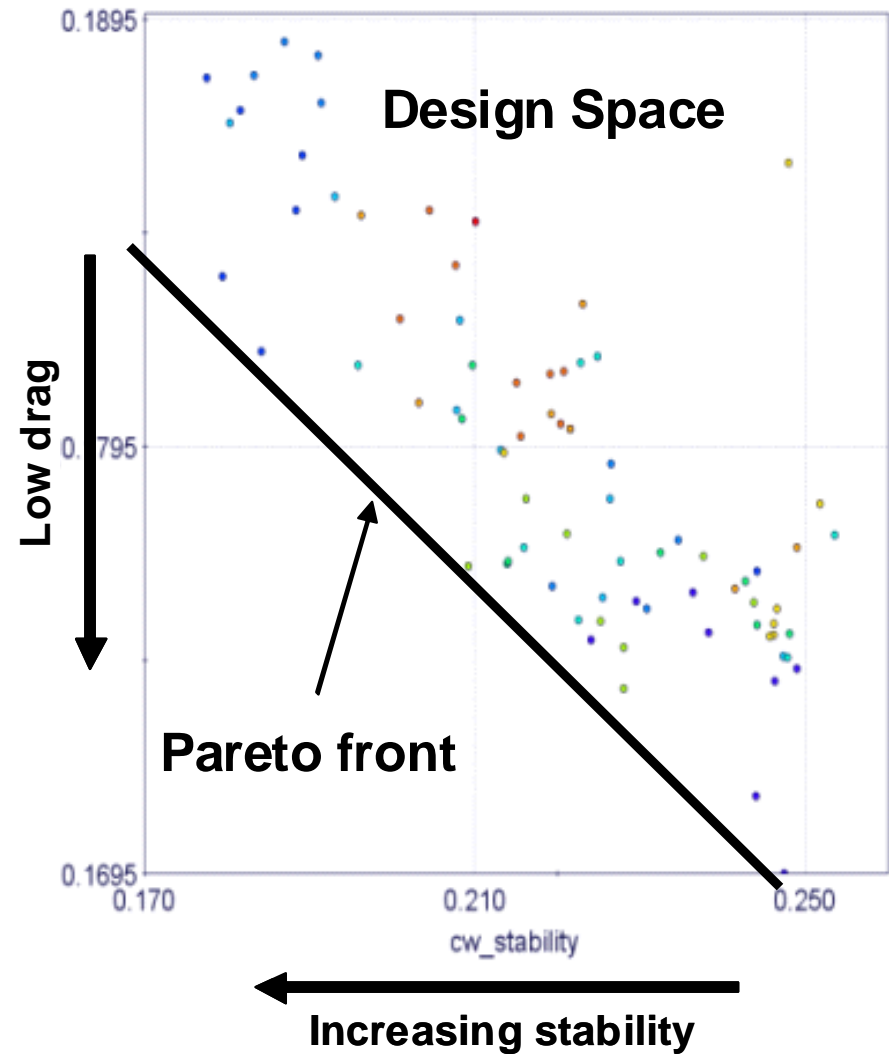
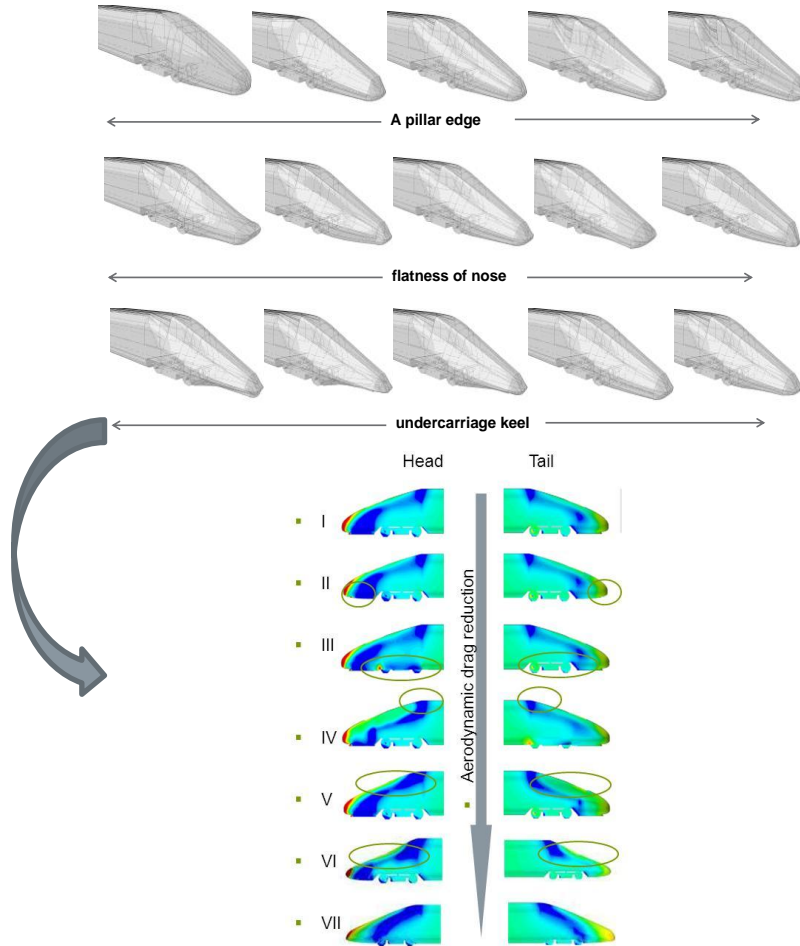
- Energy consumption is a function of the aerodynamic resistance
- Reducing the aerodynamic resistance by 20% reduces the energy consumption more or less by 10%



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MULTI-OBJECTIVE OPTIMIZATION

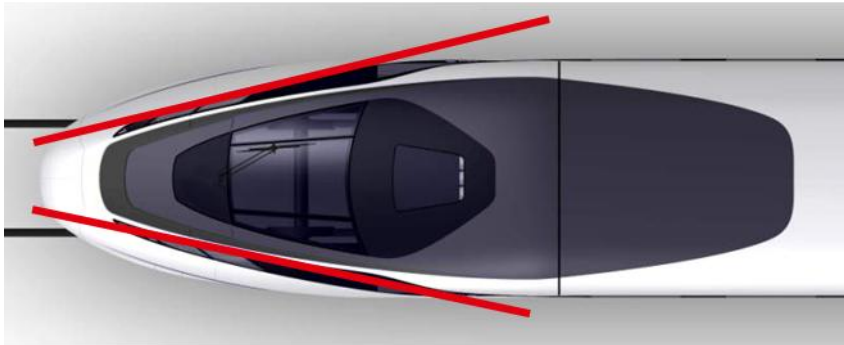
Design Space



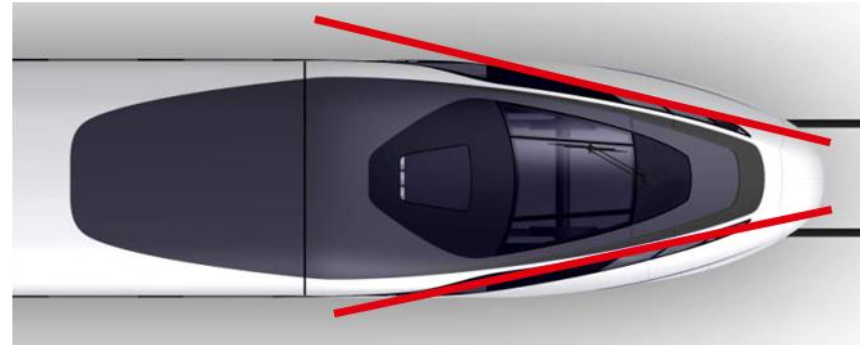
AEROEFFICIENT LOW TAIL DRAG BY PRESSURE RECOVERY

Boat tailing in upper part of the front to enable pressure recovery at the tail results in drag reduction and thus less energy consumption

Front

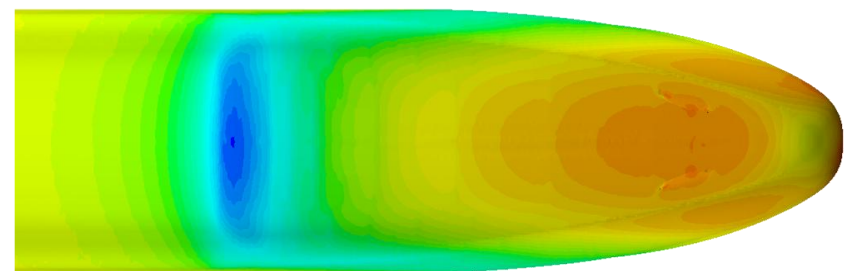
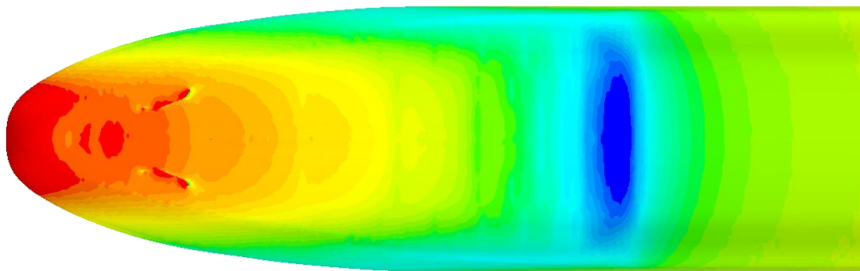


Tail



Static pressure

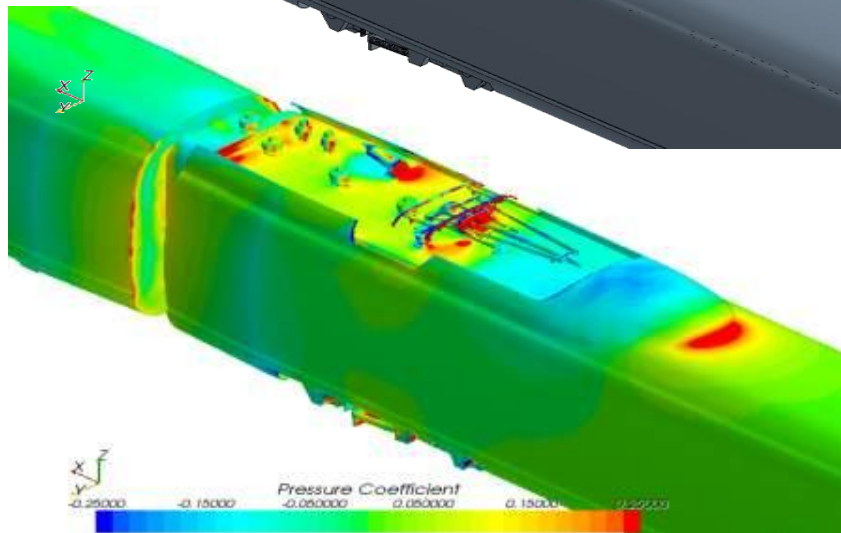
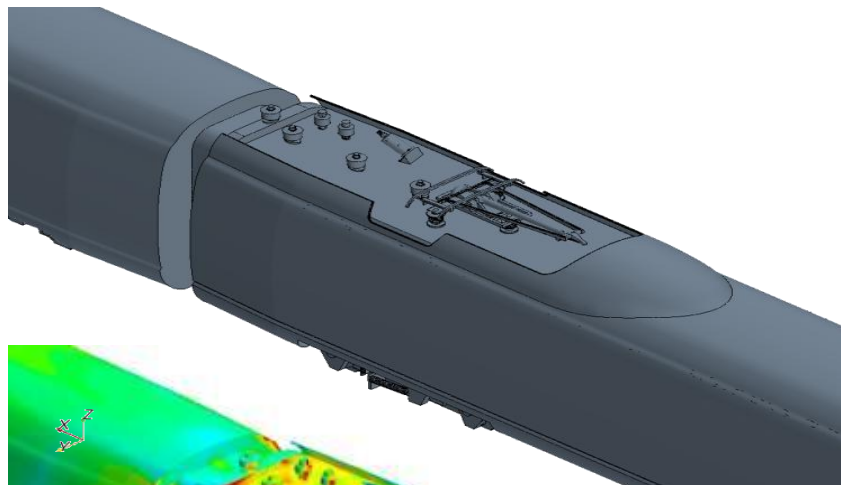
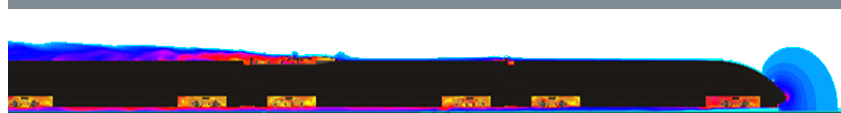
eco⁴



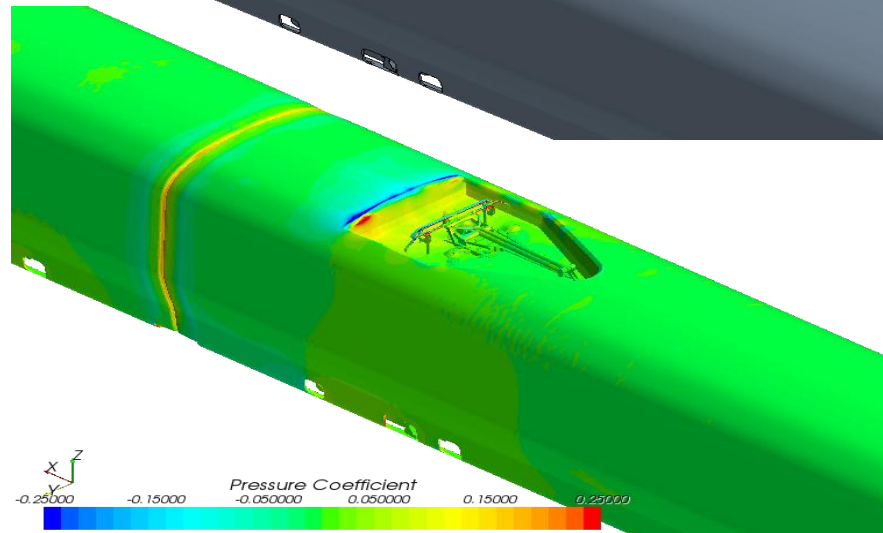
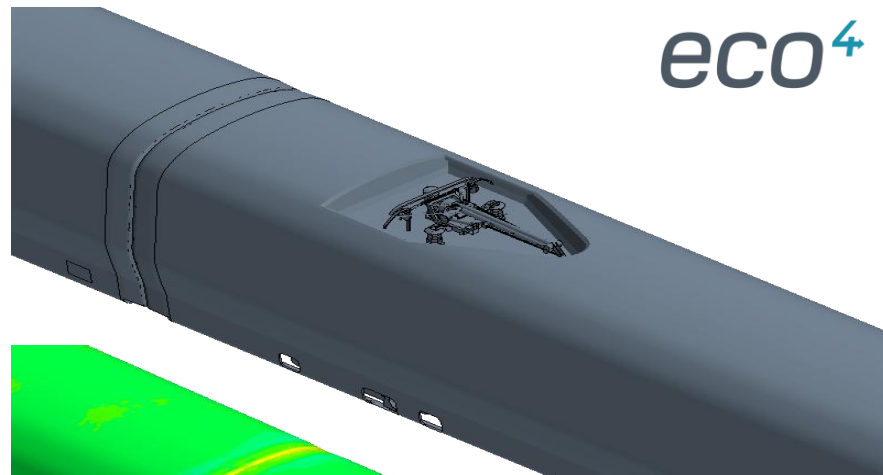
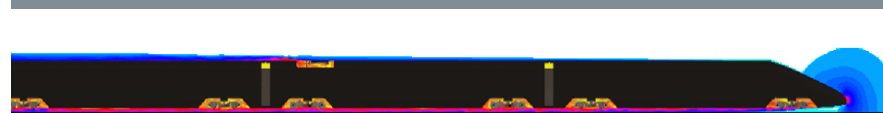
AEROEFFICIENT ROOF DESIGN

Pantograph area

ICE3



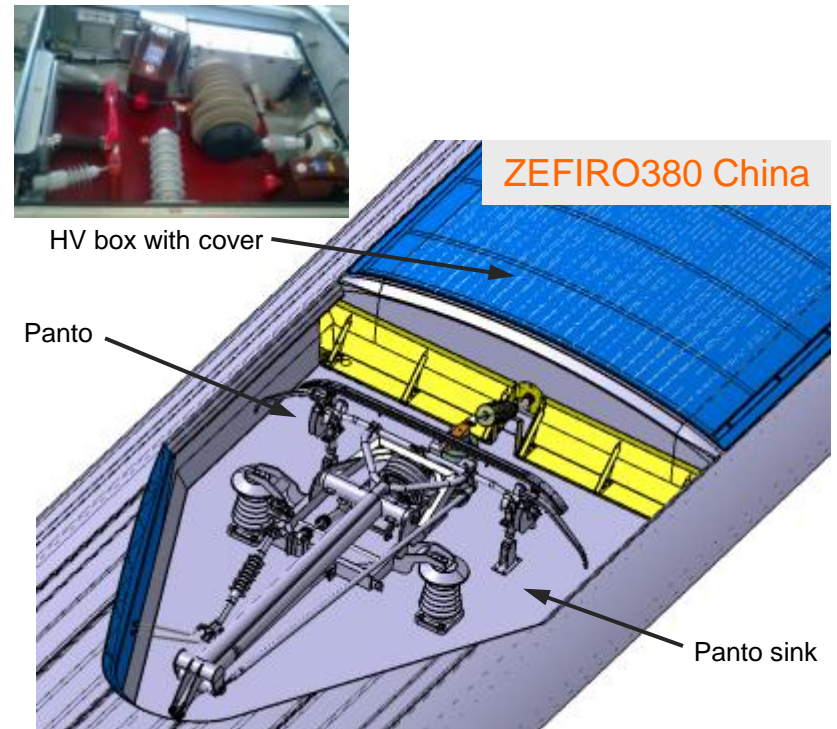
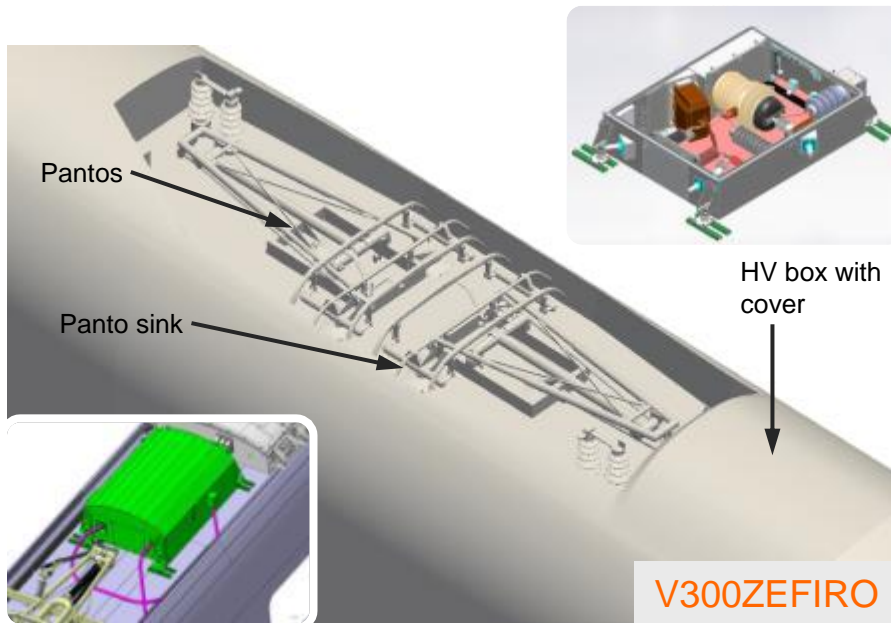
FRECCIAROSSA 1000



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ZEFIRO technology – High Voltage box & Pantograph

- In order to improve the aerodynamic and aero-acoustic performance, all high voltage components have been installed on the roof without protrusion.
- The pantograph is located in a sink. Nothing will stick out if the pantograph is in lowered position.
- All HV equipment is installed in a special HV-box which is an innovation and a unique feature on VHS trains



ZEFIRO platform bogies – For speeds up to 380 km/h

The *FLEXX* speed bogies represent a new generation of VHS bogies

Motor bogie



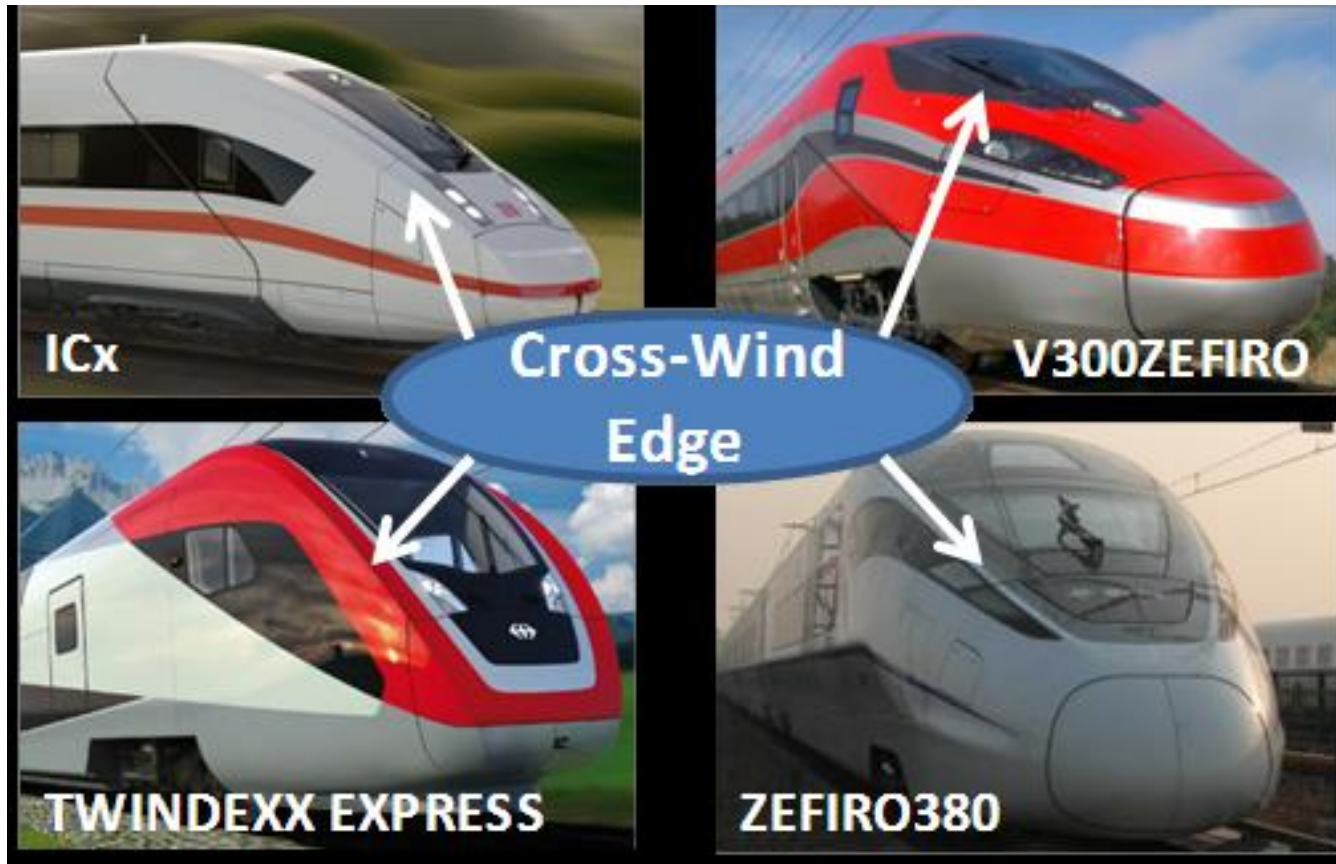
Trailer bogie



Top service speed	Up to 380 km/h		
Wheel base	2700 mm or 2850 mm		
Wheel diameter	920 mm (new), 850 mm (worn)		
Brake equipment	4 wheel disc brakes	Brake equipment	6 or 8 axle disc brakes
Total bogie weight	approx. 9.5 t	Total bogie weight	approx. 7.4 t

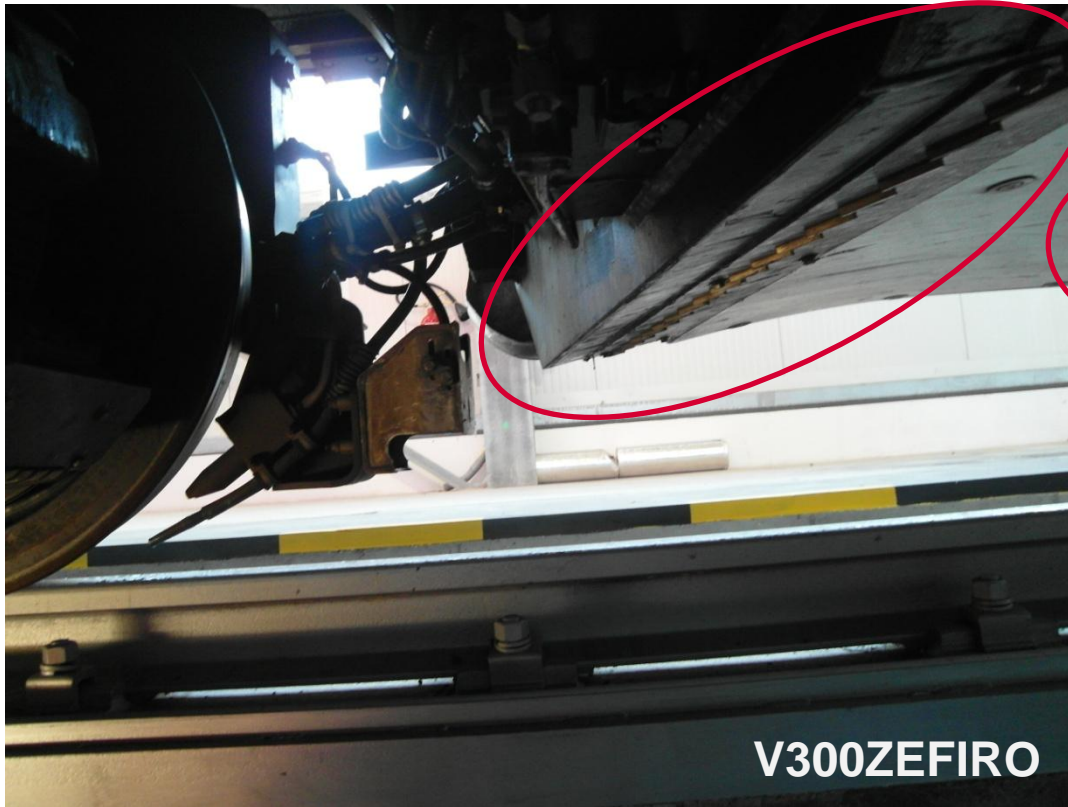
- Large wheelbase of 2.700 mm or 2.850 mm for improved running stability
- Reduced total weight and unsprung mass by improved motor mounting
- Improved for aerodynamics and ballast protection
- Prepared to integrate active elements (e.g. active lateral suspension)

BOMBARDIER'S CROSS-WIND EDGE



[6] Cross-Wind Edge: Europäisches Patent EP 2383161A1, Fahrzeugkopf mit reduzierter Seitenwindempfindlichkeit

REDUCED NOISE – TURBULANCE GENERATORS



Turbulatorplatte: Europäisches Patent EP 2428420 A1

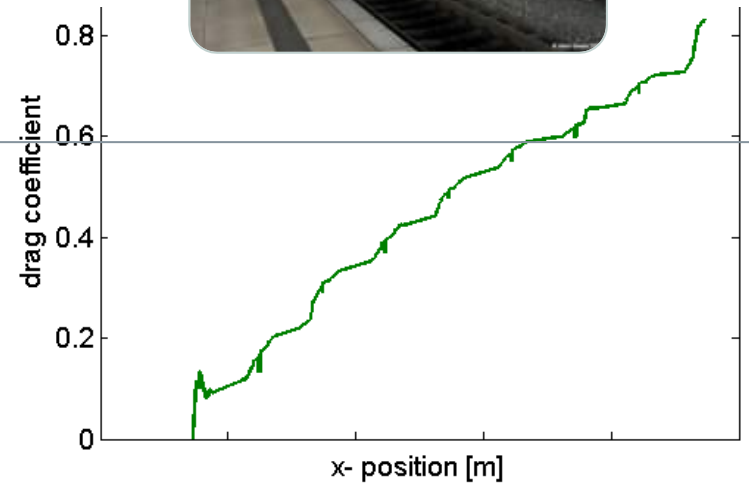
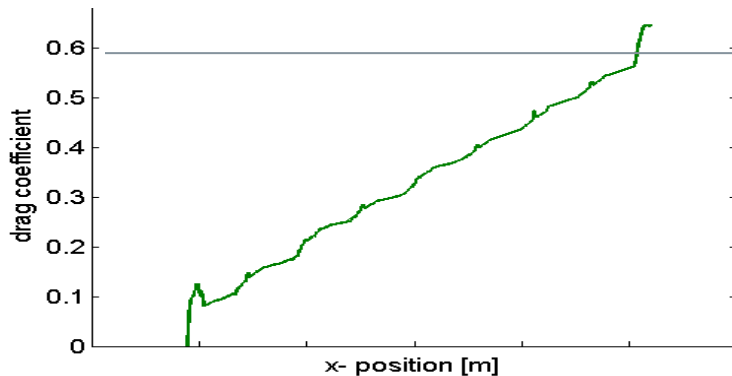
REDUCED NOISE AND AERODYNAMIC RESISTANCE – STREAMLINED AIR DEFLECTOR AT NOSE



Unterbodendiffusor: Europäisches Patent EP 2428422 A1

COMPARISON OF ZEFIRO 380 WITH ICE3

Simulation of both trains with same setup



- Best possible shape related to minimised aerodynamic resistance
- Saving around 9% of traction energy compared to current high speed train design
- World class aerodynamic performance achieved by genetic algorithms
- Around 20% lower drag compared to ICE3 despite the fact that it has a considerably higher and wider cross section

HIGH COMPETITIVENESS WITH OPTIMIZATION METHODS

Products developed with new approach



ZEFIRO 380
for MOR:

High-end
aerodynamics



TWINDEXX
for SBB:

Cross-wind
stable light-
weight high
speed double
decker



ICx
for DB:

Bombardier is
responsible for
Aerodynamics
→ highest cross-
wind stability
facilitate light-
weight end-car



V300ZEFIRO
for Trenitalia:

Fulfills all TSI
requirements
with lowest
energy
consumption due
to reduced
resistance



Régio2N
for SNCF:

Cross-wind
stable light-
weight high
performance
double decker

TOWARDS TOTAL COST OF OWNERSHIP OPTIMIZATION “MIND SET”

The ZEFIRO development is one example on how the total cost of ownership mind-set was driving decision making on concept and detailed design level related to the general concept and especially to aerodynamics and thermodynamics.

Total cost of ownership requires an “optimization” mind-set rather than a “specification” mind-set.

Bombardier’s Vehicle Engineering function is committed to extend this “optimization” mind-set to the whole vehicle with support of Product Marketing.

PROBLEM STATEMENT - TOTAL COST OF OWNERSHIP

WHERE ARE WE TODAY?

Assumption:

- LCC /TCO optimized vehicles play already a big role in the customer evaluation of our bids but will play an even bigger role in future
- Energy costs are a big portion of the LCC of a vehicle → increase efficiency of electrical consumers and reduce weight of vehicle
- Standardization of design principles and therefore on component and system level rather than on vehicle level will be the future for railway (similar to automotive, trucks or busses)

Problem Statement:

- Our products need a reduction of weight and maintenance costs and increase of energy efficiency and reliability on system and component level (e.g. bogies and traction equipment etc.) but there is no clear decision rule for our internal or external suppliers and partners to balance performance and costs during their product development phase
- Today Vehicle Engineering gives evaluation criteria during the bid phase according to the evaluation of the specific bid. But this practice is not effective as our partners/suppliers cannot make a product strategy and development in 6 months (usual bid phase duration)
- Our architect teams are therefore more and more concerned about the fact that we do not get weight and energy optimized equipment from our Interco's and suppliers

Total Cost of Ownership

System and R&D specifications today and tomorrow

Typical today's specification for a sub system looks like as follows:

- Reliability: max. 0.01 fpmk (failure per million kilometre)
- Mass: max. 50 kg
- Maintainability: max. 0.1 maintenance hours/kilometre
- Energy consumption: max. 500 W

Tomorrows specification for development goals:

- $TCO [€] < \text{value of reliability [€/fpmk]} * \text{failures [fpmk]} + \text{value of mass [€/kg]} * \text{mass [kg]} + \text{hourly maintenance rate [€/h]} * \text{maintenance need [h]} + \text{energy cost [€/kWh]} * \text{energy consumption [kWh]}$
- The key is that each responsible engineer for a sub system can make his own optimisation based on TCO with little information flow required between different systems
- Maximum values for some values might be required in order to meet constraints

Example:

- For a commuter train for Germany an evaluation was done of the TCO of the value in Euros of one kg running at the stretch envisaged. Also an evaluation of the value of one kW reduction was deducted. The calculation is based on 30 years lifetime

Result is roughly that

- each ton of mass difference would be equivalent to 18000 € and
- each kW power consumption would be equivalent to 17000 €

Conclusion on concept & technology

- The conclusion is that the most expensive material and design principle for the carbody becomes the less expensive from TCO perspective
- The customer benefit in terms of energy is higher than the additional labour costs for production and material cost

Optimisation on Vehicle Level

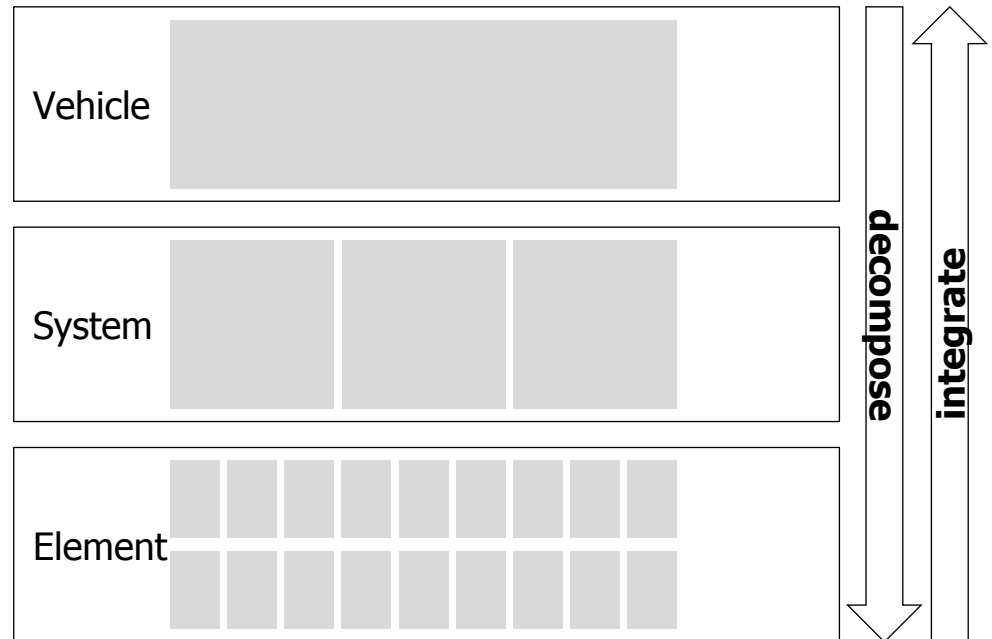
Total Cost of Ownership Optimisation

Multi-objective optimization means

- Total cost and time to market optimisation results in a cluster of Pareto-optimal designs, but no unique solution
- For a given development time (time to market) there is a unique combination of concept, system and component choice which exhibits the lowest cost

→ the Vehicle Engineering architecture work consists in finding the Pareto-optimal solution together with other Engineering functions, suppliers and Industrialisation

Time To Market Reduction: system and elements on concept level



BOMBARDIER AWARD “TOP SOLUTION” “CROSS-WIND EDGE” - ONE OF THE BEST THREE!



Acknowledgement:
Thanks to Thomas Schwiegel, Robert Kirchhof, Yves Carton, Ralf Niklass and many others within Bombardier for the “winning” team spirit during the ZEFIRO development

From left to right:

Alexander Orellano, Martin Schober, Marco Weise, Andreas Tietze,
Lower picture: Stefan Steilen

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