# High speed train vehicle dynamics – challenges and opportunities

NSJT 2012

Rickard Persson

BOMBARDIER

# On the agenda

- The vehicle
- The organization in a vehicle dynamics point of view
- Opportunity: Influence the track quality
- Challenge 1: Stability at high speed
- Challenge 2: Select a wheel profile
- Challenge 3: High speed curving
- Challenge 4: Ride comfort
- Challenge 5: Behaviour at suspension failures
- Challenge 6: Homologation

# The vehicle

The V300Zefiro is manufactured by Bombardier in cooperation with Ansaldo Breda for the Italian operator Trenitalia.

- 50 eight-car train sets (400 cars)
- Conventional train configuration
- 202 m total length
- 360 km/h top speed
- Married pair motor and trailer car -> 50% driven axles
- Multi-power supply (2 or 4-systems)
- High cant deficiency curving

V300Zefiro mock-up, Innotrans 2012





BOMBARDIER

# The organization from a vehicle dynamics point of view


Västerås (ride comfort)

Derby (bogie design, running safety)

Hennigsdorf (project management, carbody design)

Vado Ligure (project management, final assembly)

Ansaldo Pistoia (carbody design)

**Politecnico Milano**





BOMBARDIER

# The organisation in a vehicle dynamics point of view

**Bogies Derby (UK)**

derailment safety

running stability

track loading

**Mainline Västerås (SE)**

ride comfort

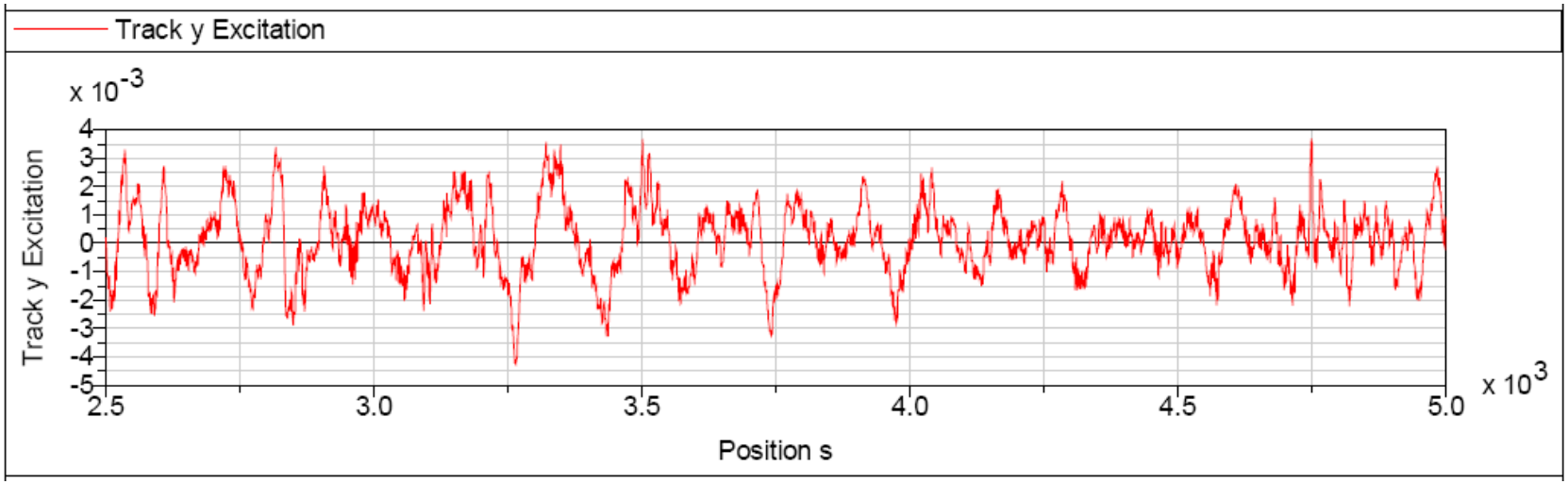
sway coefficient

movements

crosswind resistance

# Opportunity: Influence the track quality

- The maximum speed on Italian tracks today is 300 km/h.
- Italian tracks are measured in the wave length interval 3 – 25 m.




Opportunity: To influence the track quality requirements

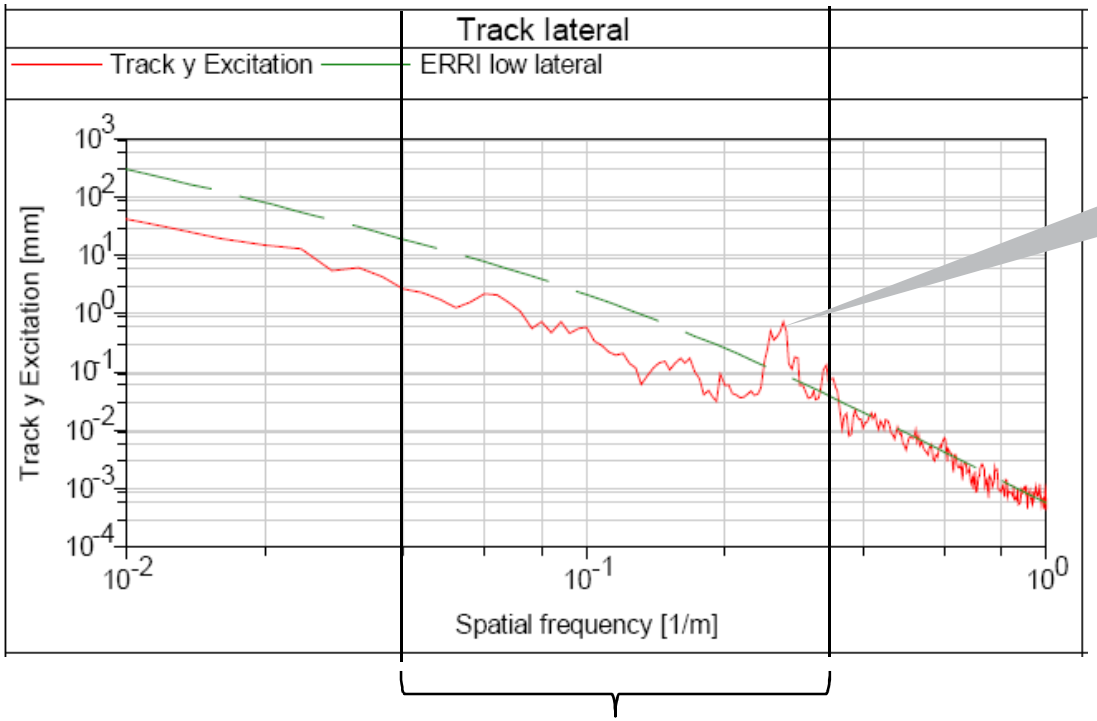
Challenge: Design a vehicle for undefined track quality





BOMBARDIER

# Opportunity: Influence the track quality




Peak at 3.5 m wave length

1 – 3 m and 25 – 140 m wave lengths were added based on Swedish tracks

Take the opportunity!

Italian 300 km/h track

At 360 km/h this corresponds to excitation frequencies of 4 – 33 Hz
At 100 km/h this corresponds to excitation frequencies of 1 – 9 Hz

Frequency range do not overlap weighting curves for ride comfort according to EN12299





BOMBARDIER

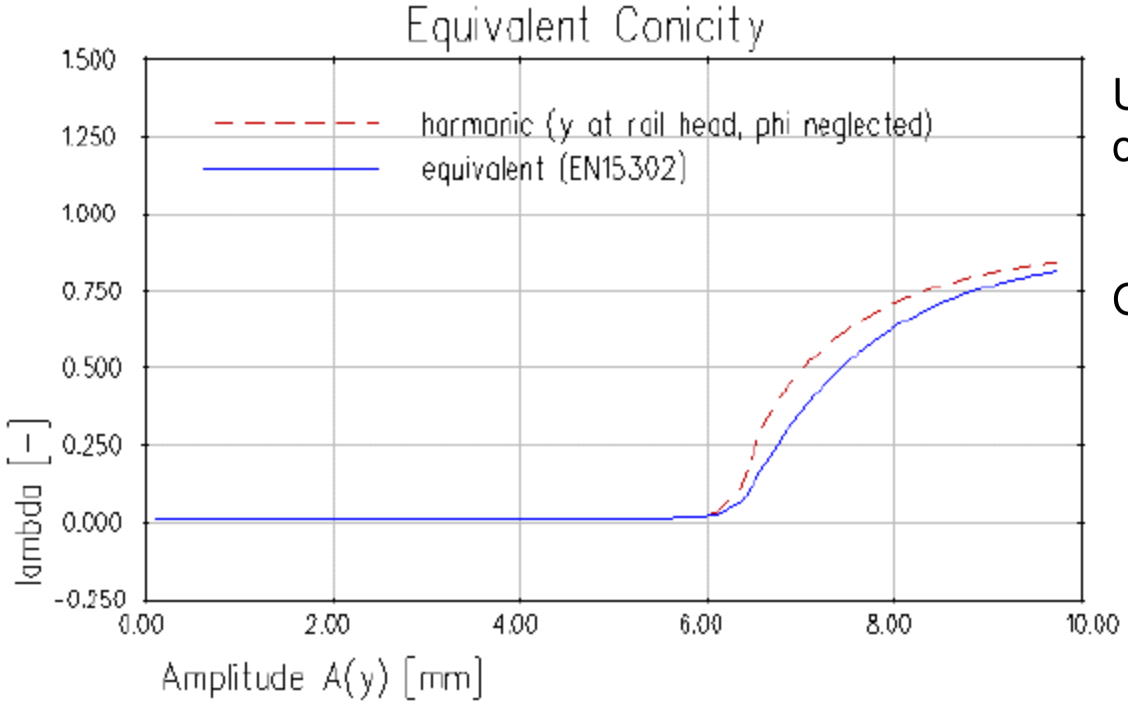
# Challenge 1: Stability at high speed

- The bogie should run stable at 360 km/h (+10%)
- The bogie should run stable at 300 km/h without yaw damper on one side

- Bogie with long axle base
- Stiff primary suspension
- High yaw damper rate
- Wheel profile avoiding high conicity

# Challenge 2: Select a wheel profile

- 360 km/h on dedicated high speed lines
- 250 km/h on conventional lines
- Different rail profiles (types and wear)
- Different rail inclinations (1:20 and 1:40)




UIC S1002 wheel profile
on UIC60 rail inclined 1:20

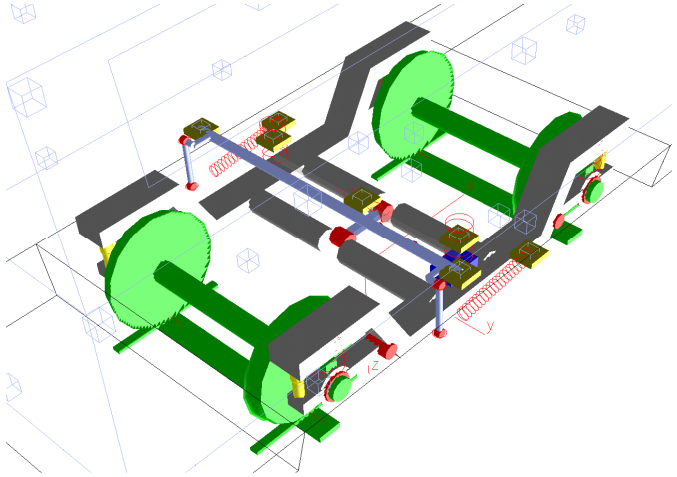
Good for 360 km/h on straight track?





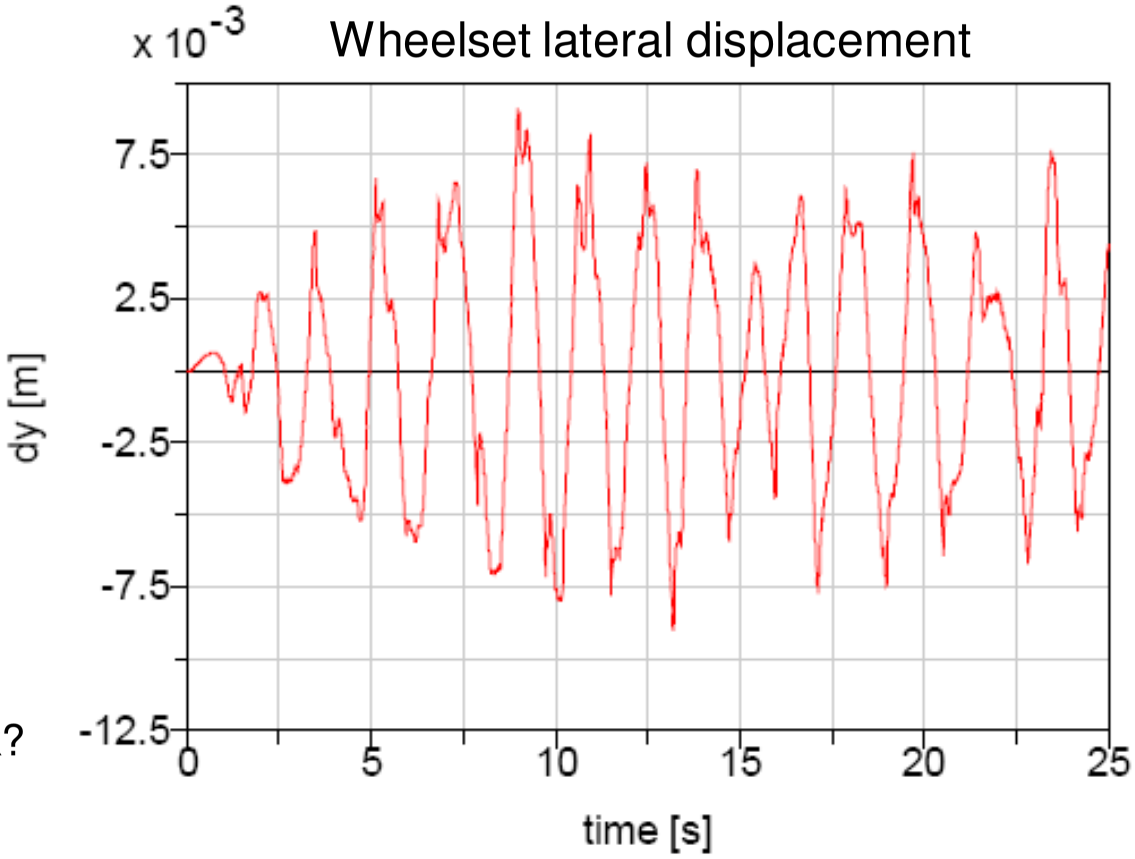
BOMBARDIER

# Challenge 2: Select a wheel profile



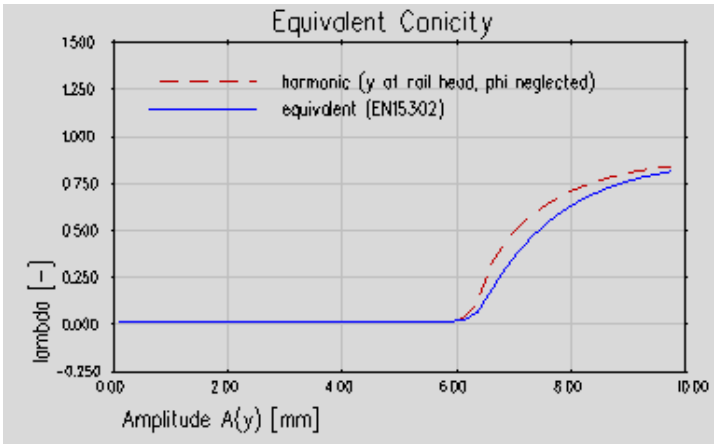
UIC S1002 wheel profile
on UIC60 rail inclined 1:20

Good for 360 km/h on straight track?

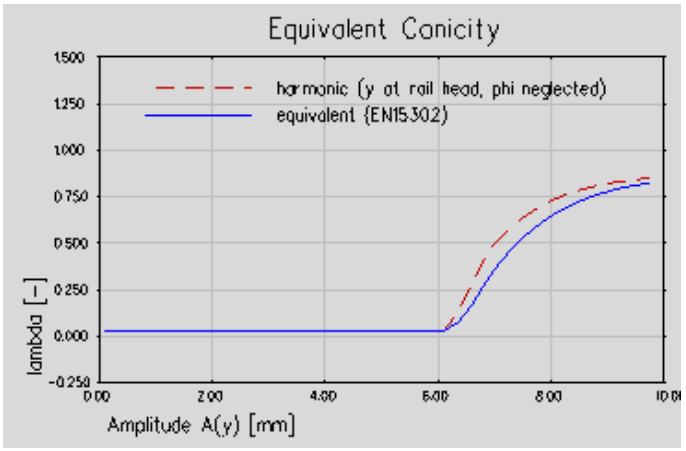



Select a wheel profile that gives higher initial conicity.

# Challenge 2: Select a wheel profile




S1002 on UIC60 incl. 1:20




ENV40 on UIC60 incl. 1:20

The conicity normally increases with wheel wear.



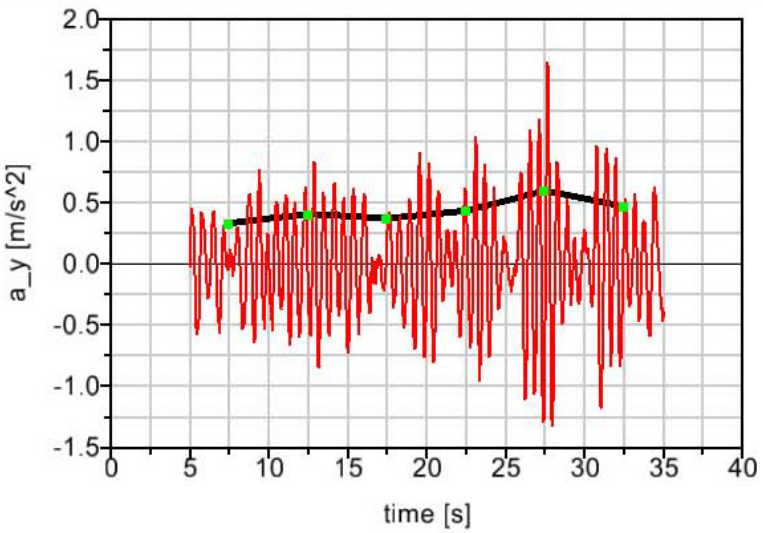


BOMBARDIER

# Challenge 3: High speed curving

## Cant deficiency comparison

| | TSI | | EN13803-1 | | V300Zefiro |
|---|---|---|---|---|---|
| Speed range | Normal limit | Max limit | Normal limit | Max limit | Specification |
| *230 < v ≤ 250 km/h* | 100 mm | 150 mm | 130 mm | 153 mm | 153 mm |
| *250 < v ≤ 300 km/h* | 100 mm | 130 mm | 100 mm | 130 mm | 153 mm |
| *v > 300 km/h* | 80 mm | 80 mm | | | 153 mm |




Weighted carbody lateral acceleration
at high cant deficiency and high speed

Stay away from the lateral bump stops



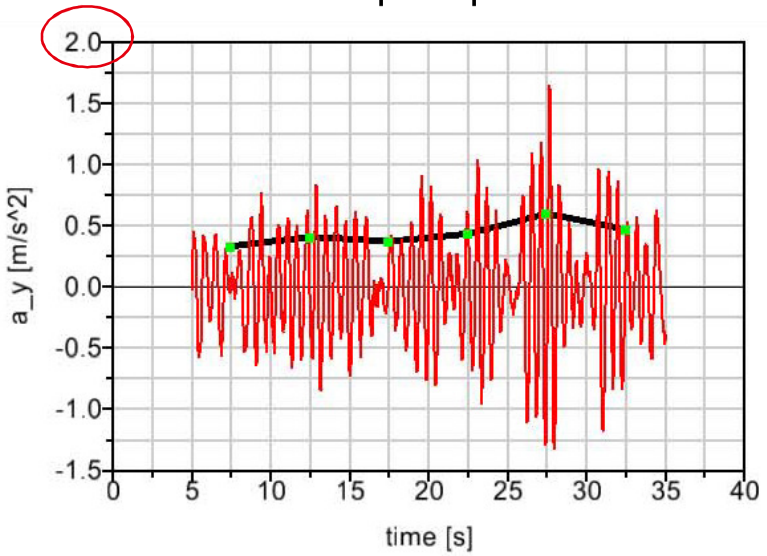


BOMBARDIER

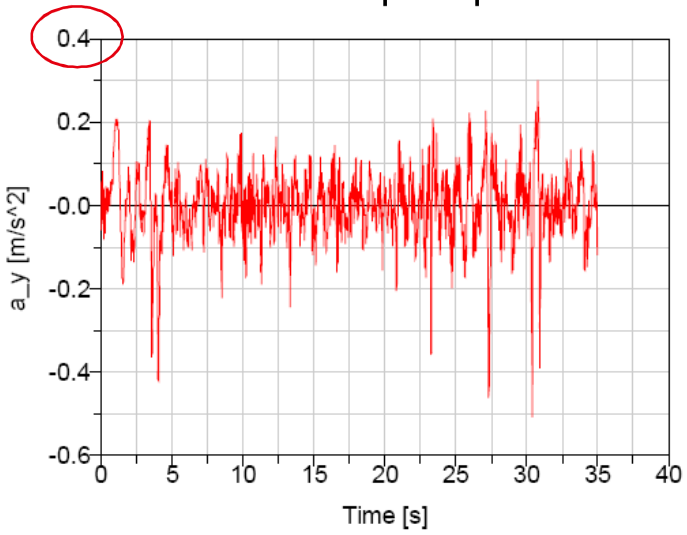
# Challenge 3: High speed curving

Weighted carbody lateral acceleration at high cant deficiency and high speed

With bump stop contact




Without bump stop contact




Active Lateral Suspension sold on 400 high speed cars!





BOMBARDIER

# Active lateral suspension

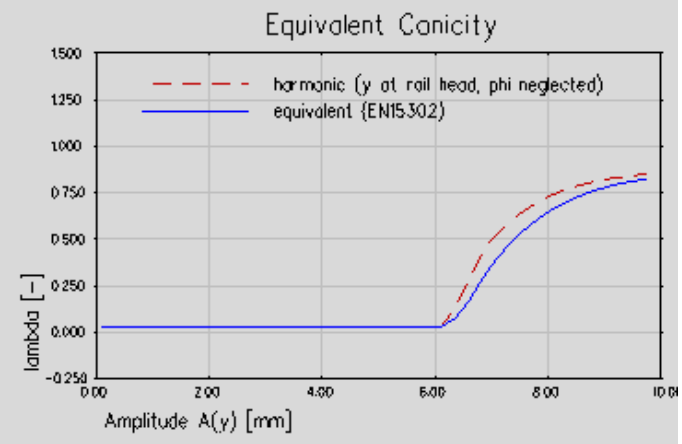

Active lateral suspension is a *Hold-Off-Device* and *active damping* in one hardware.

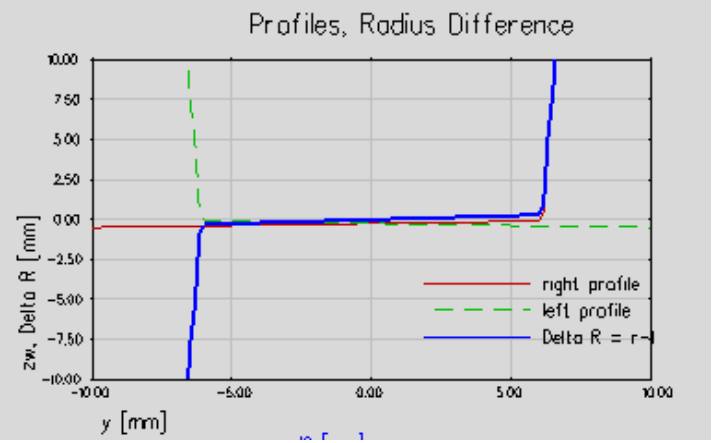
The actuator takes the place of the lateral damper between bogie and carbody


Challenge: Design a ALS for a high speed train

Opportunity to influence
ride comfort and carbody width

# Challenge 3: High speed curving




ENV40 wheel profile on UIC60 rail inclined 1:20

Good for curving?

The wheelset will run with flange contact for most curve radii as the radius difference is too small to allow radial steering

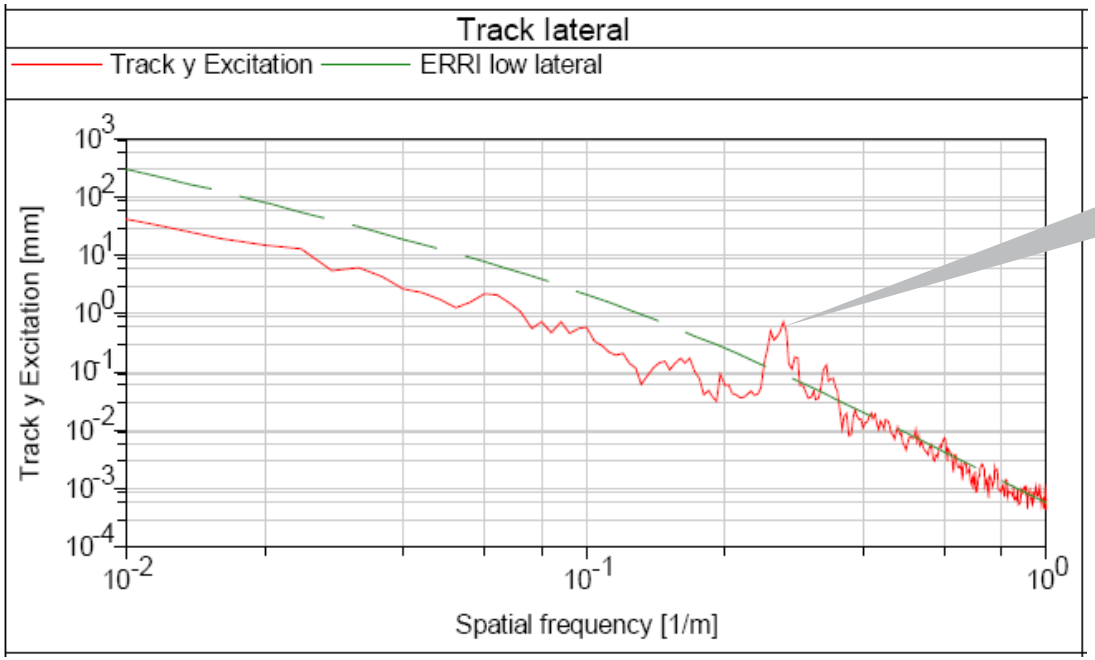
Opportunity: Influence the wheel profile





BOMBARDIER

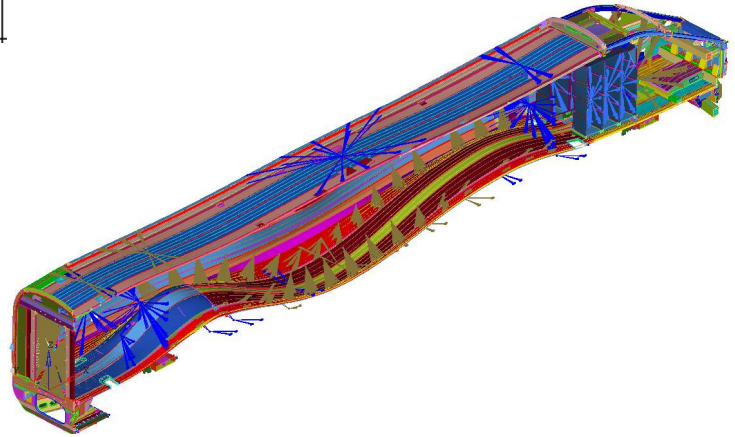
# Challenge 4: Ride comfort




Peak at 3.5 m wave length

The 3.5 m wave lengths will initiate frequencies up to 30 Hz depending on speed

Challenge: Avoid influence from local modes







BOMBARDIER

# Challenge 5: Behaviour at suspension failures

- Yaw damper on one side failed – continued service at 300 km/h

  What happens?

  Bogie rotation centre moves to the other yaw damper
  The effective yaw damping becomes small
  300 km/h without yaw damping?

- Active lateral suspension disabled – continued service at full speed

  What happens?

  The ALS works like a passive damper
  Bump stop contact
  Worse ride comfort accepted

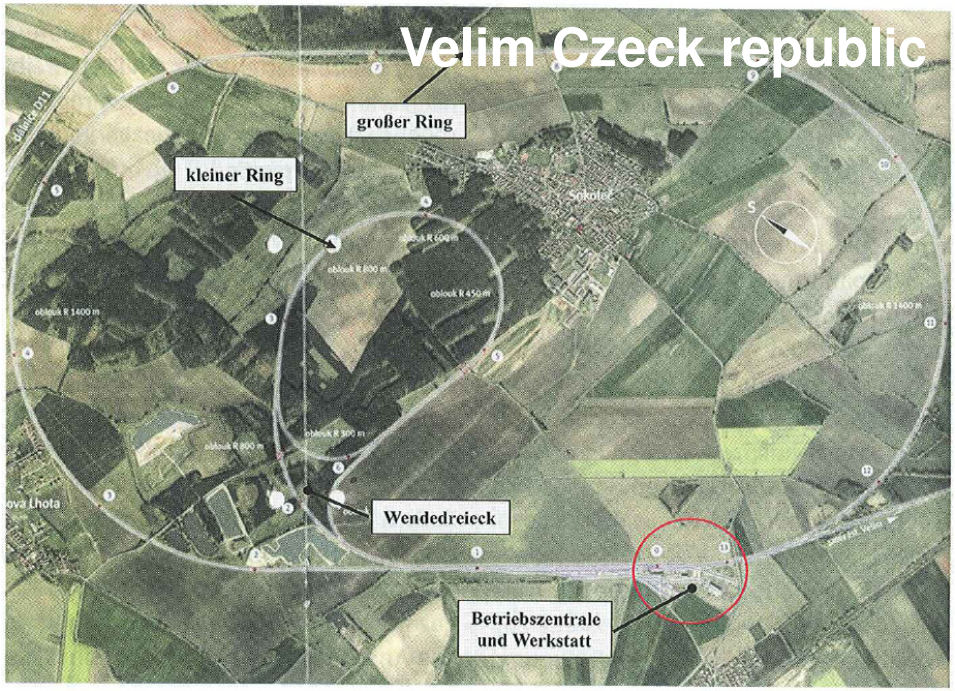
- Active lateral suspension fails – safe transition to disabled als

  What happens?

  The ALS may enforce bump stop contact
  The wheel sets follows the outer rail in curves
  The primary suspension is laterally stiff
  Will a vehicle connecting the carbody to track laterally with little flexibility meet requirements on track forces?

# Challenge 6: Homologation

- Five train sets used in parallel for homologation
  1) Braking and electric interference
  2) Vehicle dynamics and pantograph
  3) Automatic train protection and multiple operation
  4) Climate and multiple operation
  5) Safety and endurance
- Two years calendar time
- Test sites
  a) Vado Ligure shop
  b) Vado Ligure test track
  c) RFI conventional track
  d) RFI high speed track
  e) Velim test track
  f) Vienna climate tunnel



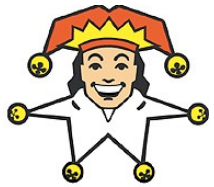





BOMBARDIER

# Challenge 6: Homologation

- It must be ensured that all tests are made under safe conditions
  - Vehicle dynamic performance must ensured during all tests
- Train software is part of the homologation
  - It must not be changed after the test
  - Release of software revisions must be planed carefully



- Operation in several countries
  - Meeting TSI is not sufficient in some countries
  - Tests must be repeated
  - Local tests to be added

# Conclusions

- Lacking track specification gives challenges and opportunities
- Bogie stability is a main concern for operators as well as manufactures, but excessive requirements on stability has a price
- Selecting a wheel profile becomes a delicate issue for a train that should be able run at so different tracks as the V300Zefiro
- Active lateral suspension made high speed curving possible, but also challenges on how to handle disabled modes and failure cases. This become particularly evident when installed in a high speed bogie
- Homologation has become a time demanding and logistically difficult part of producing a train.