2nd CFES Workshop
Control of Transportation Systems
23rd March 2010

Control Engineering Challenges for Future Railway Vehicles

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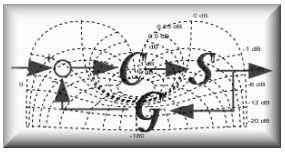

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Presentation plan

- Introduction
  - UK railway industry: structure and trends
  - Railway research: framework and current opportunities
- Railway vehicles in general
  - Principal sub-systems
  - Overview of opportunities for control
- A specific control-related opportunity
  - Active control of vehicle dynamics
- Conclusions
  - Research challenges

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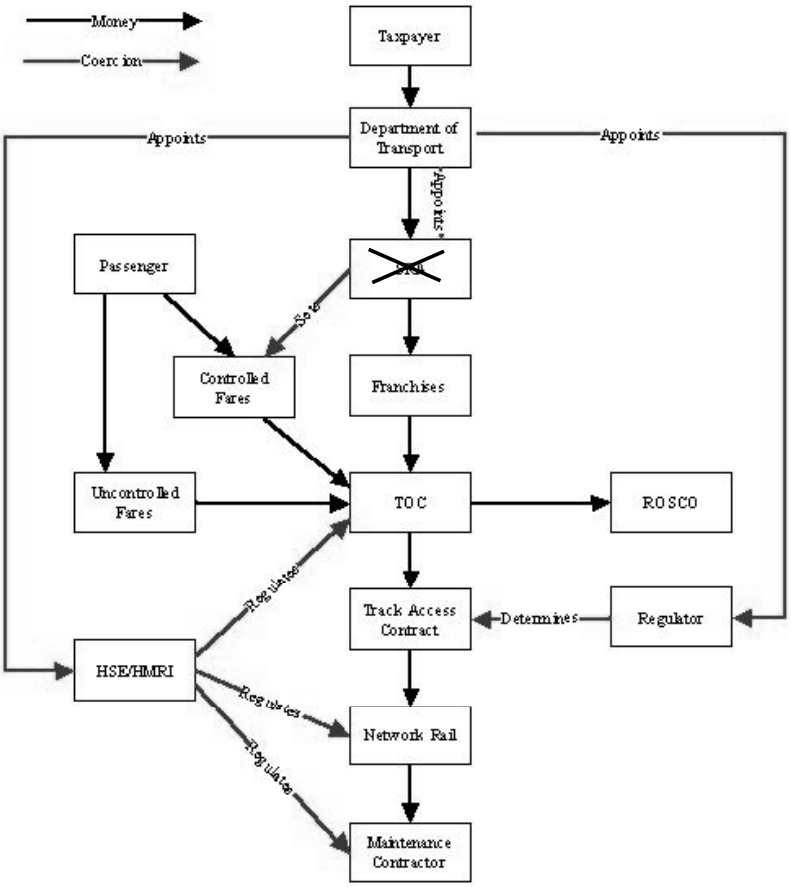

UK Railway industry structure

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Key imperatives for the railway industry

The "four Cs" from the 2007 Railway Technical Strategy* …

- **Carbon** – reducing environmental impacts
  - Target – 50% reduction
- **Cost** – significantly reducing the unit costs
  - Target – 50% reduction
- **Capacity** – expanding capacity to meet increased demand
  - Target – 100% increase, i.e. to meet twice the current usage
- **Customers** – meeting higher customer expectations
  - Target – 90% reduction in passenger dissatisfaction

Carbon	??
Cost	??
Capacity	??
Customers	??

* *Available on the DfT website at*

http://www.dft.gov.uk/about/strategy/whitepapers/whitepapercm7176/railwhitepapertechnicalstrategy/

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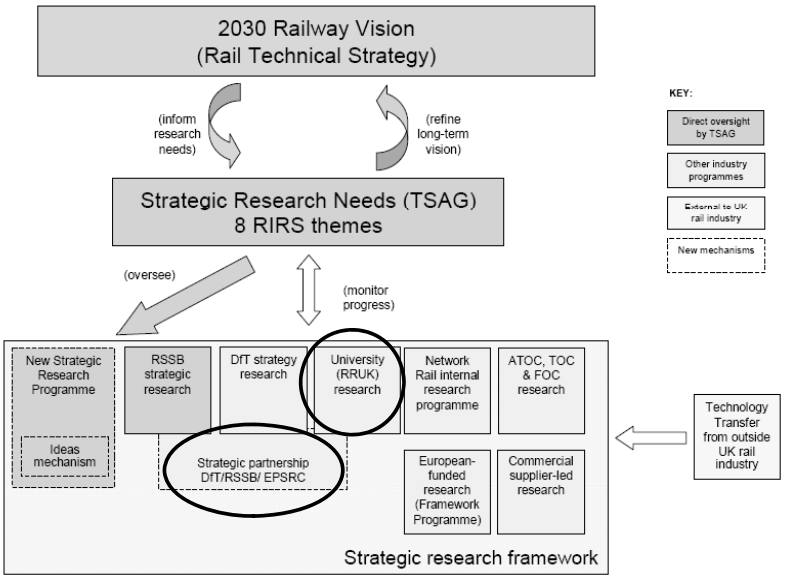
Strategic Rail Research Framework *



* *http://www.dft.gov.uk/pgr/rail/researchtech/research/implementationplan*

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The cost (price?) of railway travel

SNCF Paris-Lyon £0.30 /mile !!

- Typical UK ticket price is £0.64 /mile per passenger *
- Typical car cost is £0.40/mile (4 passengers?)
  - *BUT variable cost is £0.15 /mile*

** MML Sheffield-London Standard Single*

→ Cost matters, a lot!!

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Vehicle weight trends

- UK Pendolino train 919 kg/seat
- Japanese Shinkansen train 540 kg/seat
- *Further reductions* *470 kg/seat*

But … Ford Focus 315 kg/seat

Weight ≈ Energy → important!!

Summary of railway research environment

So …

- Well-defined priorities for railway research
- Universities are recognised to be part of the research framework
- Initiatives under way
  - » *Real opportunities for university research*

But … the industry is very complicated with lots of stakeholders

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Sub-systems in a railway vehicle

1	Car body
2	Car body fittings
3	Bogies and running gear
4	Power System
5	Propulsion
6	Auxiliary systems
7	Braking System
8	Interiors
9	On board vehicle control
10	Passenger Information System
11	Communication systems
12	Cabling and Cabinets
13	Door System
14	HVAC
15	Tilt system
16	Lighting
17	Coupler

Bogies and running gear

Sub-system elements:
- Bogie linkage
- Bogie frame
- Primary suspension
- Secondary suspension
- Wheel set system
- Auxiliary systems

Current technology:
- Inboard axleboxes
  - reduced mass bogies
- Active secondary suspensions
- Anti-RCF wheel profile

Future possibilities:
- Active steering, “mechatronic” bogie
- Composite bogie frames?
- Lightweight wheelsets (composites)
- Bogie-less configurations
- Alternative to the airsping?
  - remove/reduce pneumatics

Carbon	↓
Cost	↓↓
Capacity	→
Customers	→

Current collection

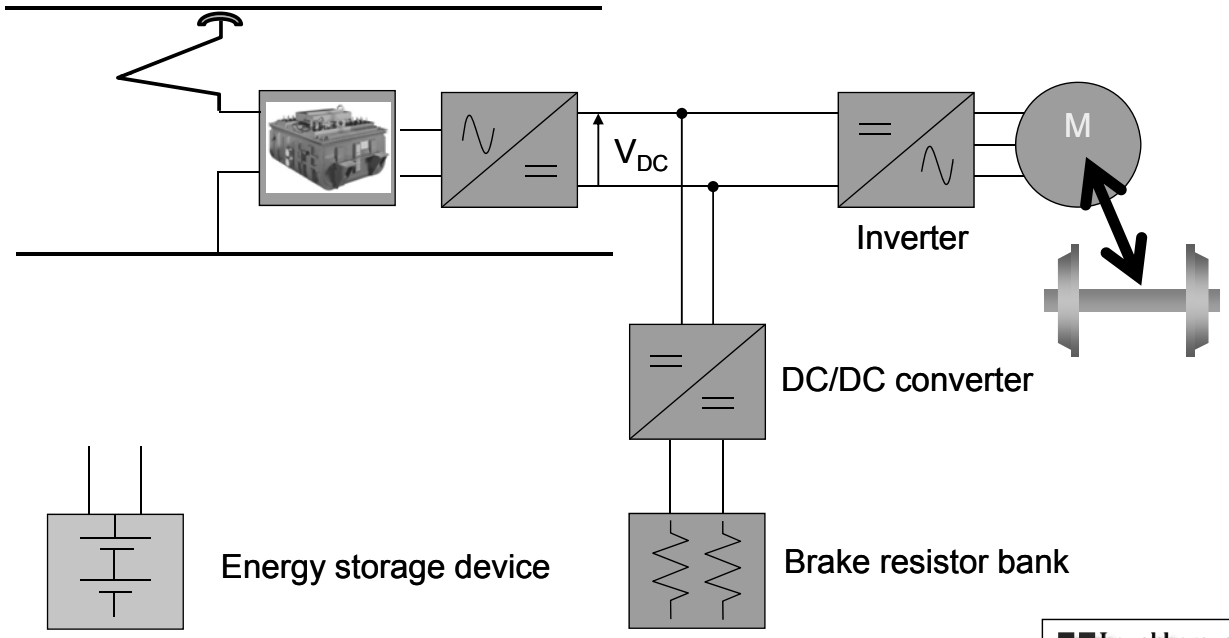
Sub-system elements:
- (Overhead line)
- Pantograph
- Transformer

Current technology:
- Well-optimised pantographs (?)

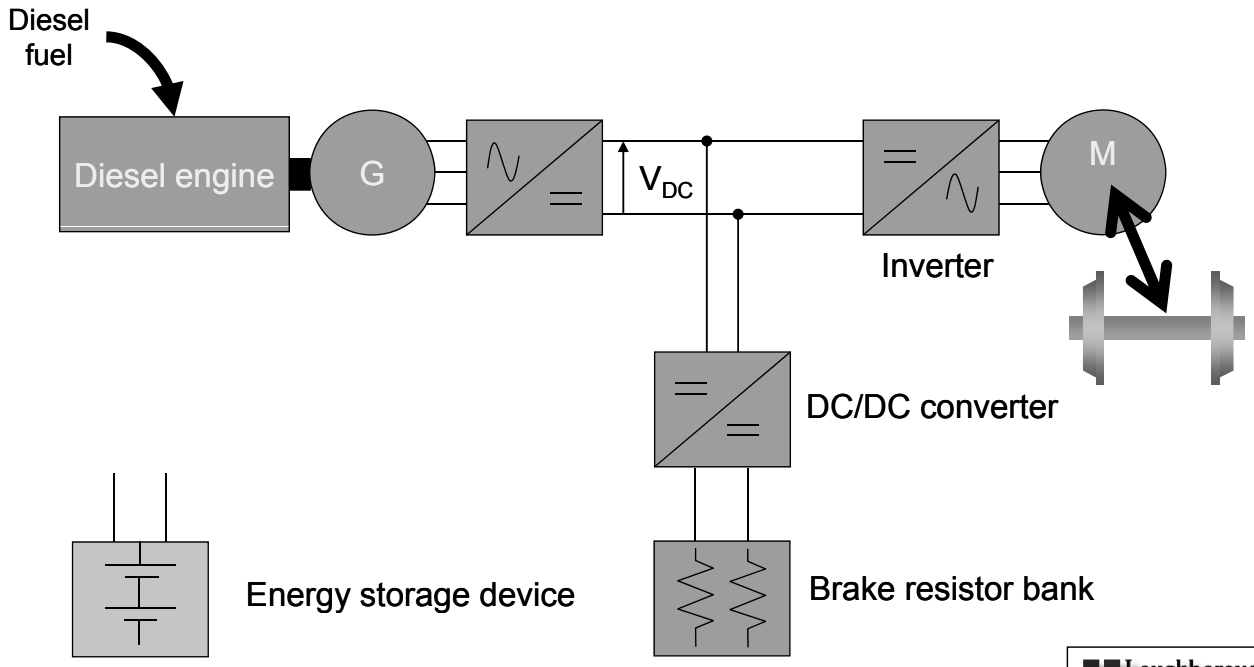
Future possibilities:
- Active pantographs
  - ~ Reduced static and dynamic contact forces
    - Less wear of the contact strips
    - Less wear of the contact wire
  - ~ Possibly an effective way to meet European standards?

Carbon	→
Cost	↓
Capacity	→
Customers	→

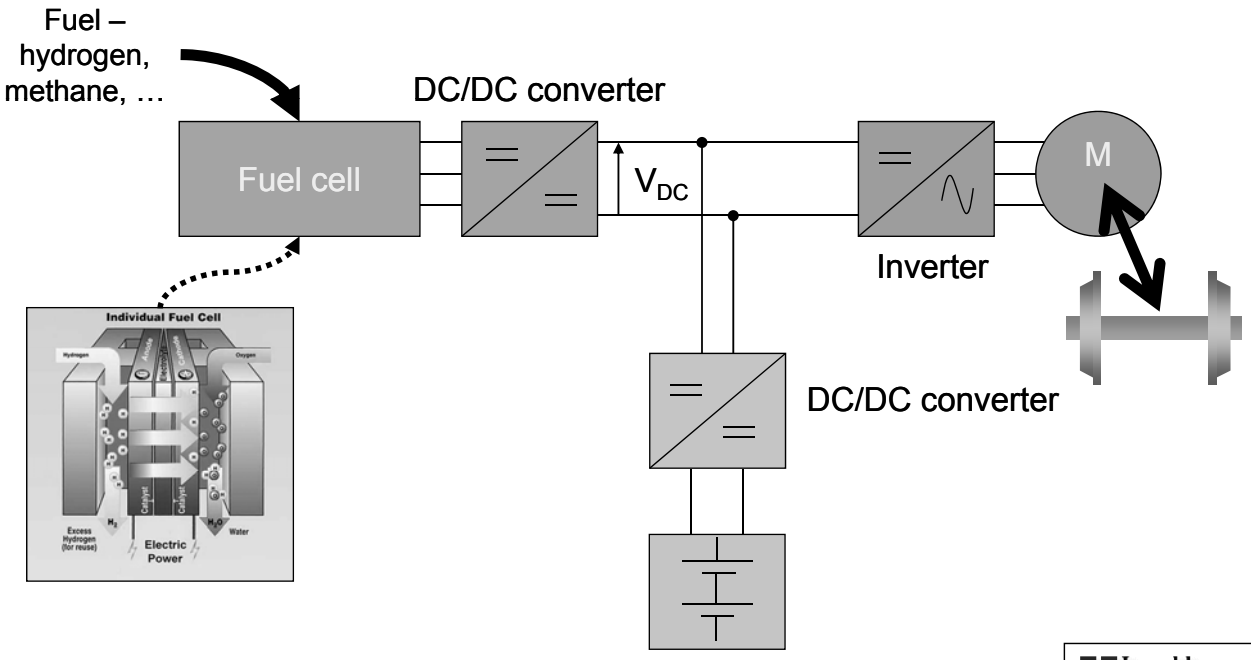
Electric Traction scheme



Diesel-Electric Traction scheme



Future non-electric Traction scheme



Power and propulsion system

- Power supply (including current collection)

- Power generation
- Power conversion
- Power dissipation
- Power (energy) storage
- Traction Control Unit (TCU)
- Gear box
- Traction motor
- Mechanical transmission
- Power converter

Carbon	↓↓
Cost	↓
Capacity	→
Customers	→

Braking system

Sub-system elements:
- Brake control system
- Friction brake equipment
- Wheel Slip Protection (WSP)
- Magnetic track brake equipment
- Emergency brake equipment
- Eddy current brake equipment

Current technology:
- Effective WSP?
- Mechatronic integration of control electronics with brake gear
- High temperature (low mass) composite wheel discs

Future possibilities:
- Alternative actuation technology
  - ➢ No pneumatics?
- Further WSP improvements
  - ~ Absolute train speed measurement?
- General trends in traction creating lower requirements for friction brakes
  - ➢ Backup and parking only?

Carbon	→
Cost	↓
Capacity	↑
Customers	→

Tilt system

Sub-system elements:
- Tilt Control Unit
- Actuating System
- Pantograph tilt system
- Tilt monitoring and detection

Current technology:
- Electro-mechanical actuation
- Well-developed tilt controllers
- Progression towards track database driven systems

Future possibilities:
- Solution to motion sickness issue
  - ~ integrated tilt and active lateral suspension control?
- High-integrity tilt control action
  - ➢ Tilt always operational

Carbon	↓
Cost	→
Capacity	↑
Customers	↑

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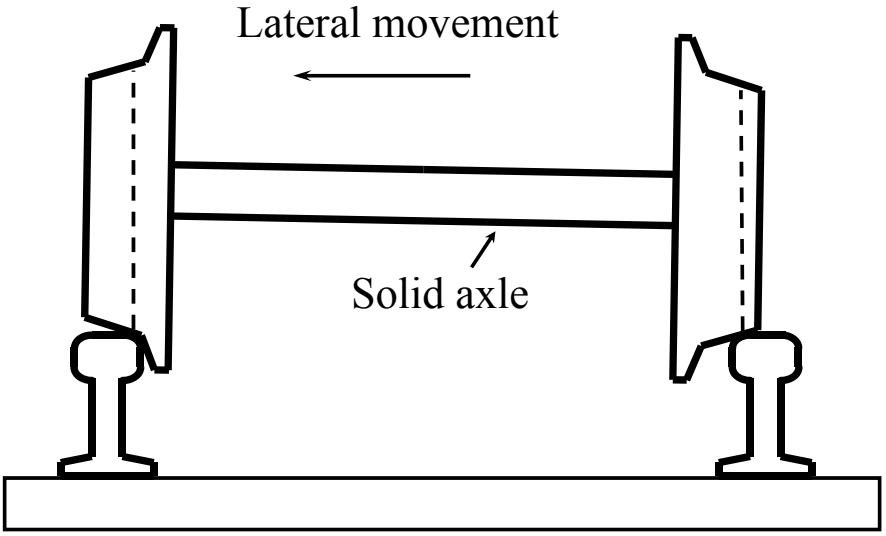
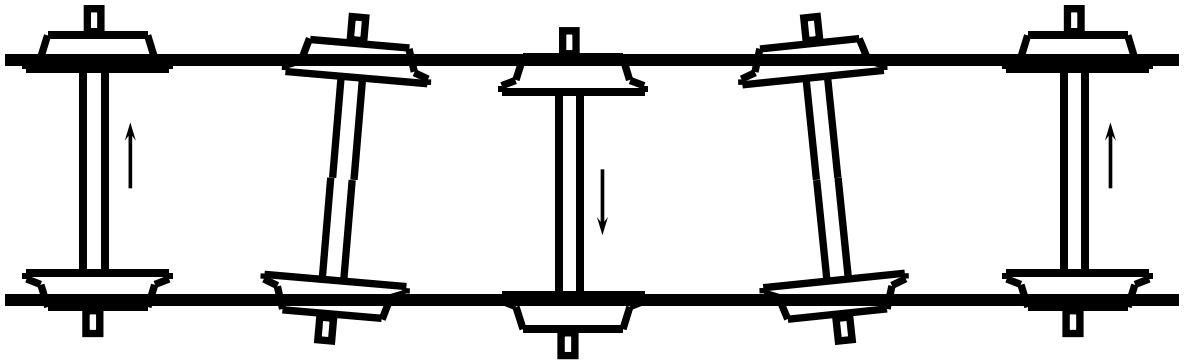
Stability and guidance, not ride quality

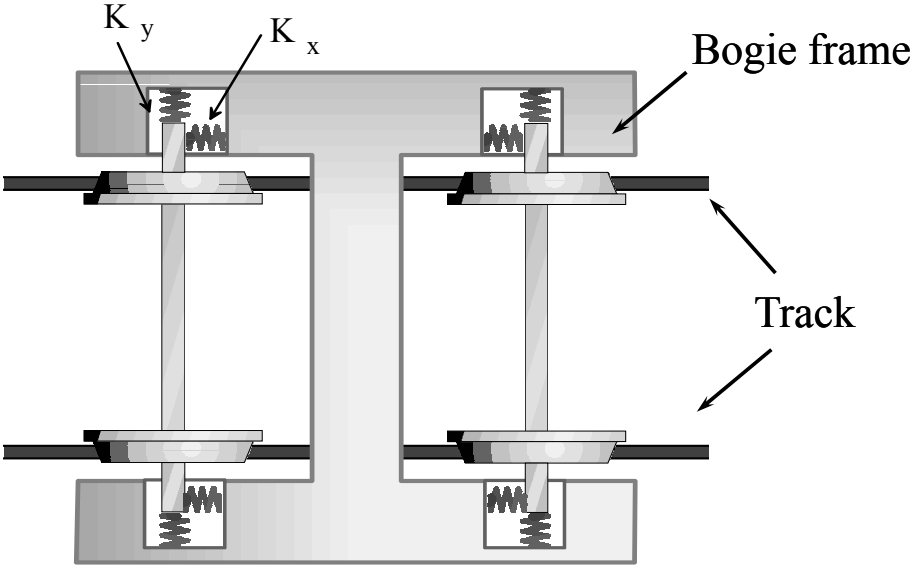
Wheelset on a curve



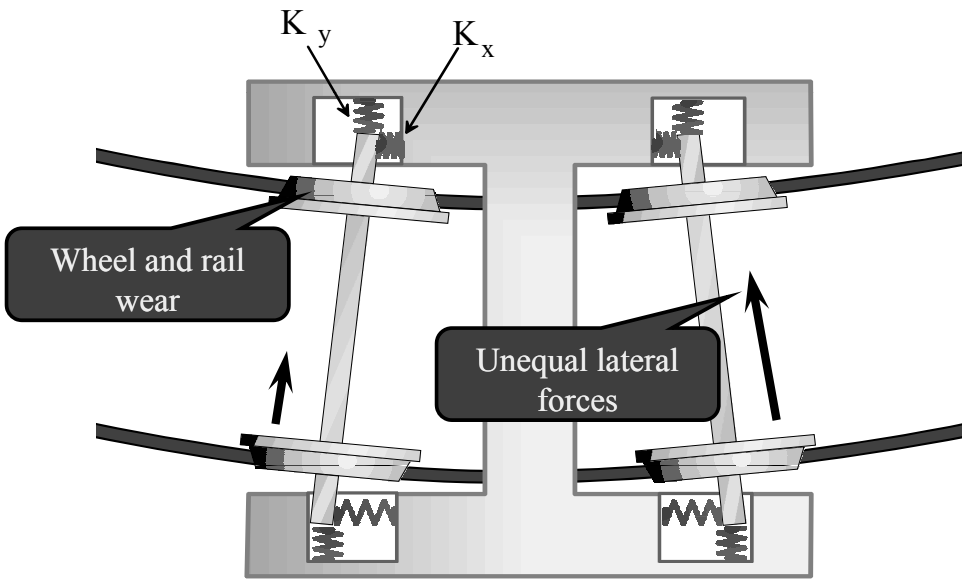
Wheelset “hunting”



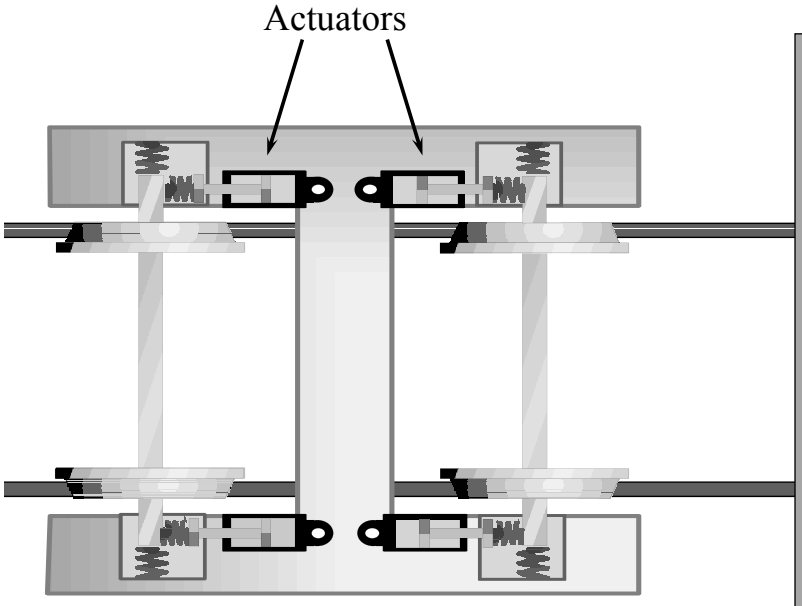
Wheelsets in a bogie



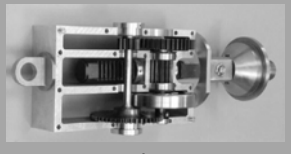
On a curve



Active control

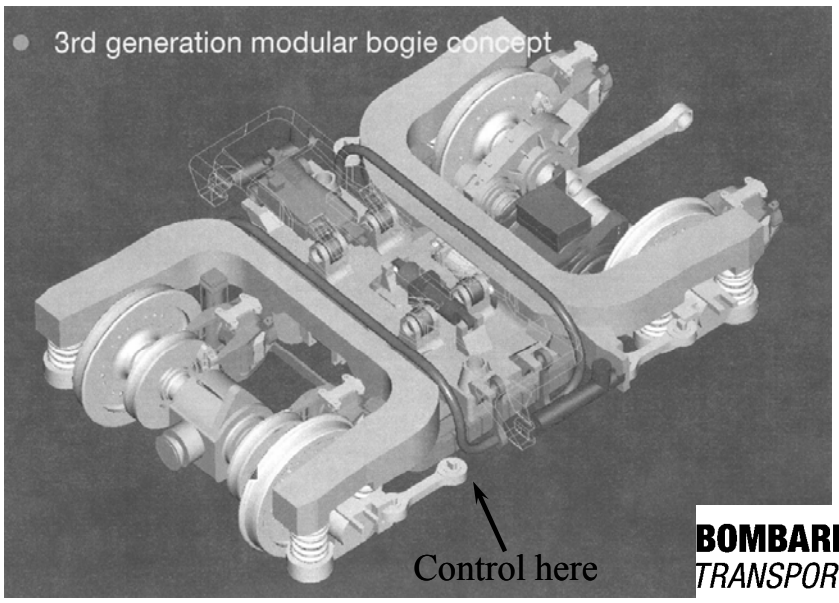


Project collaboration with Malcolm Smith:-
Use of inerters and their potential for integration with active control using actuators



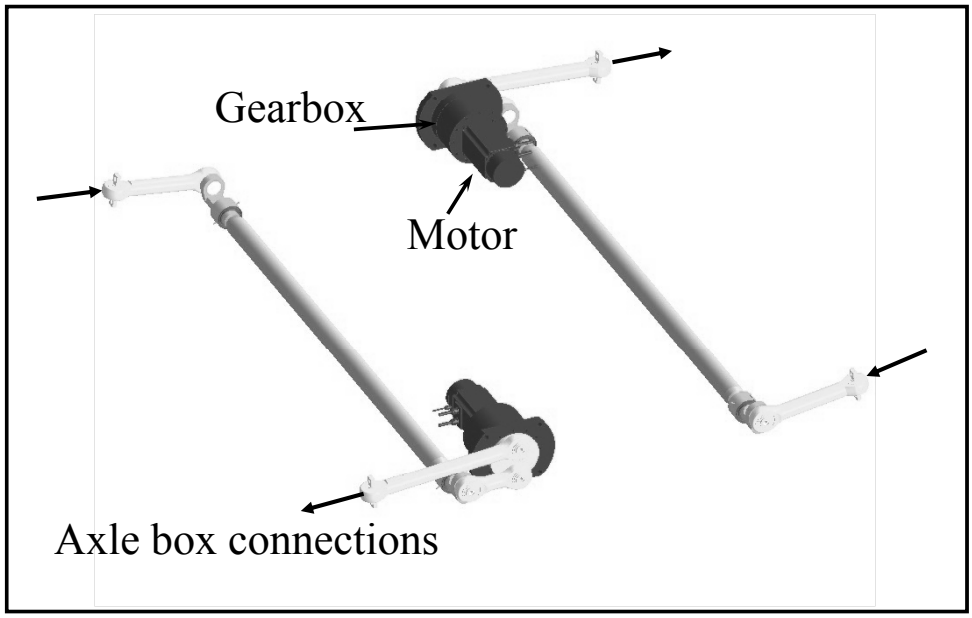
+

Mechatronic bogie

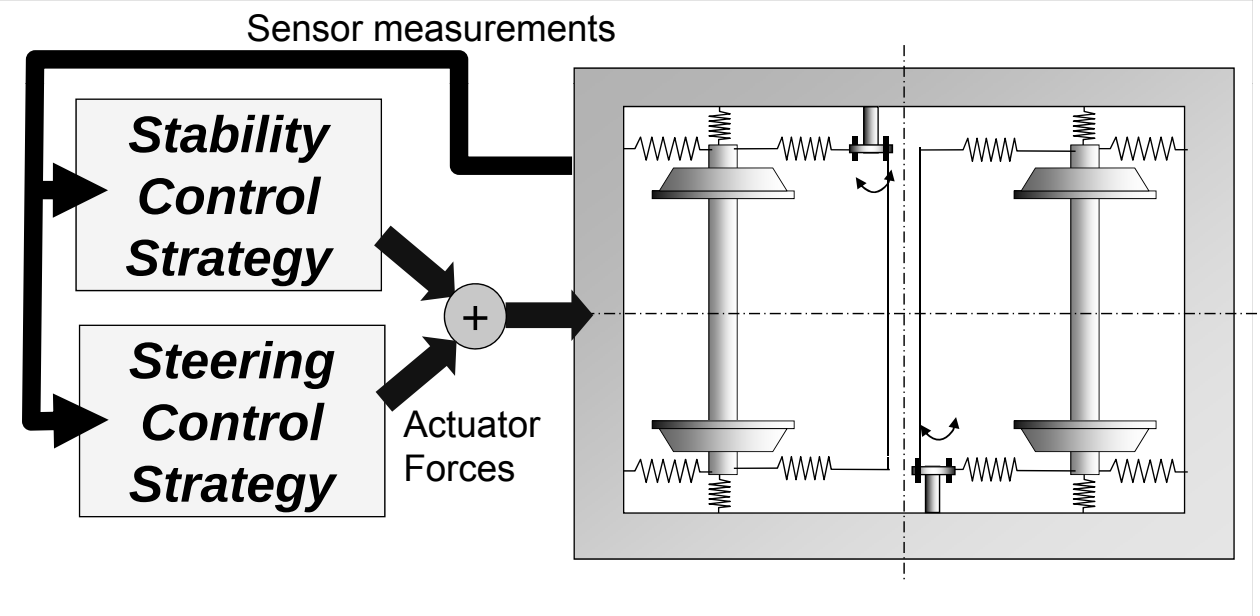


BOMBARDIER TRANSPORTATION

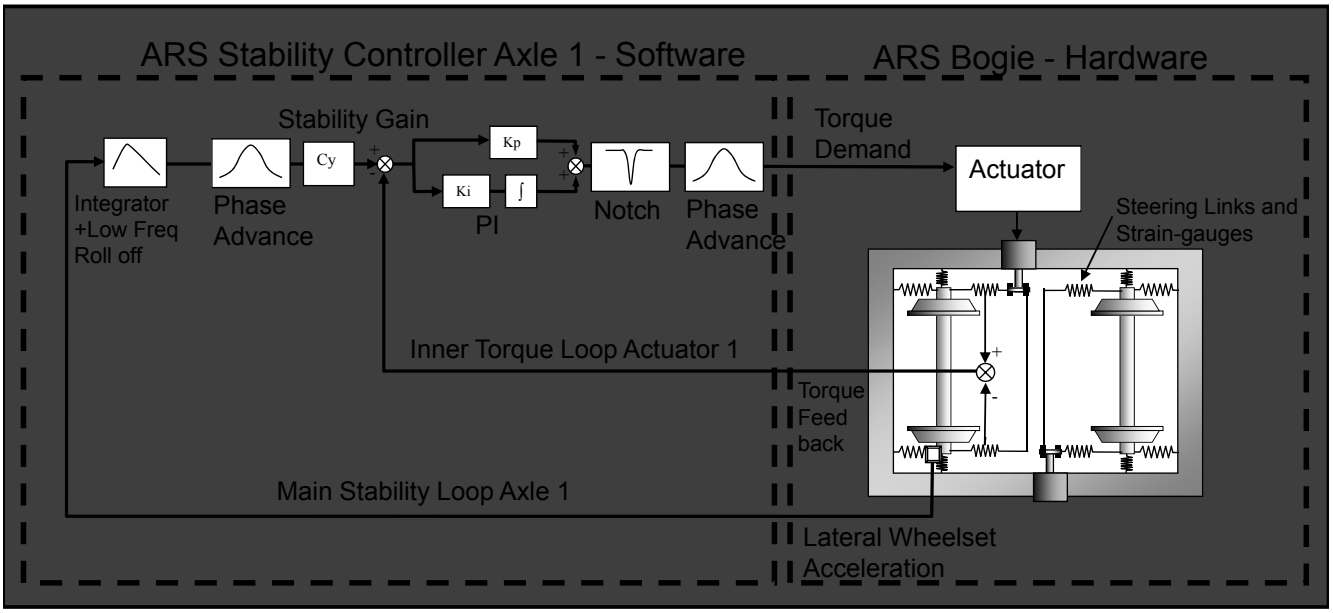
Control mechanism



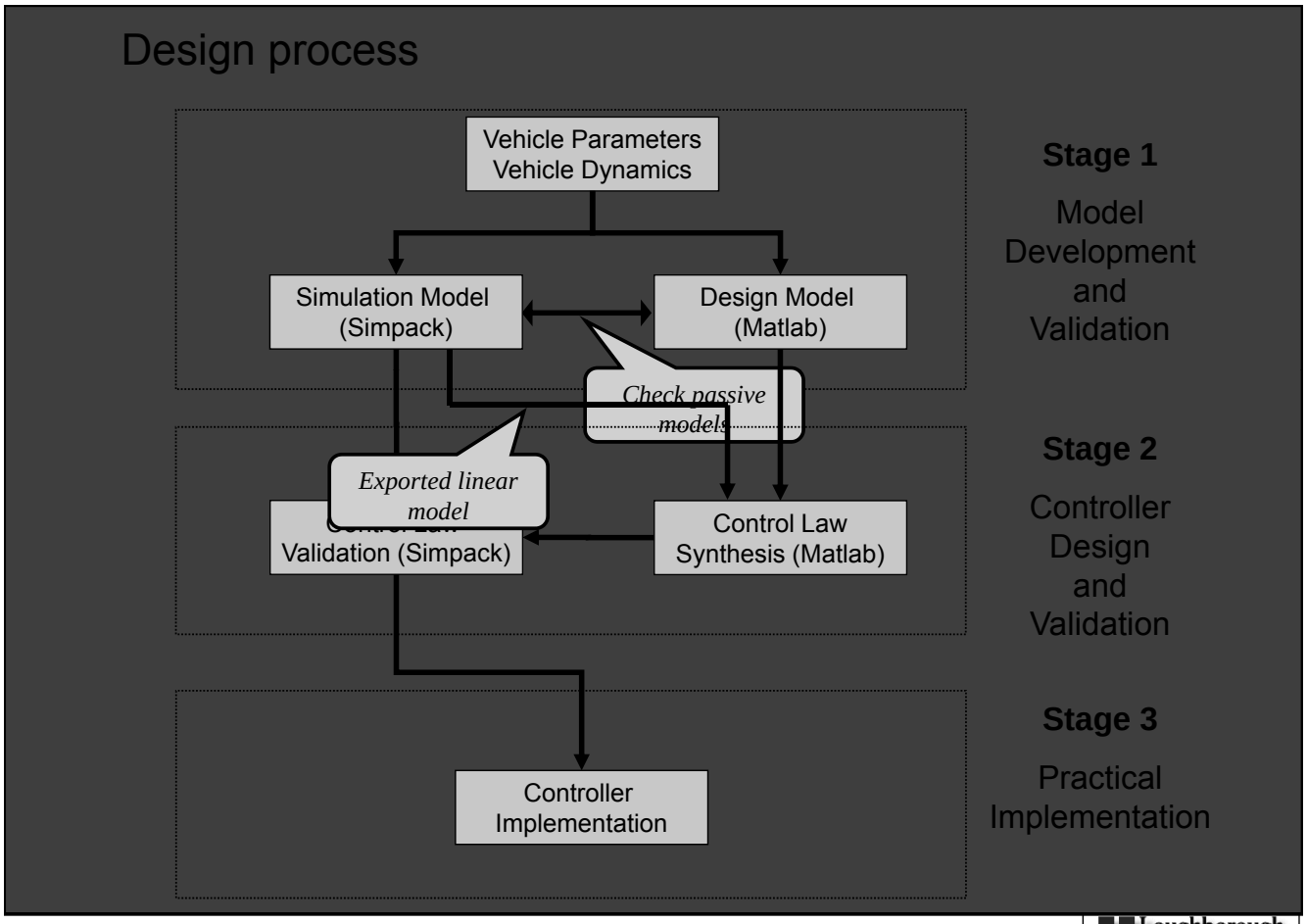
High level control scheme



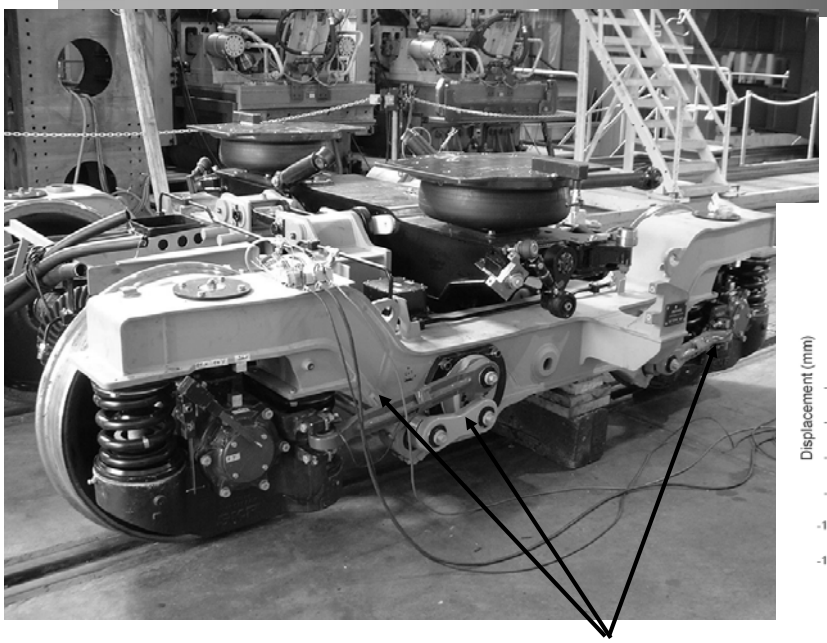
Control scheme – more detail



Design process



Experimental bogie



Steering links

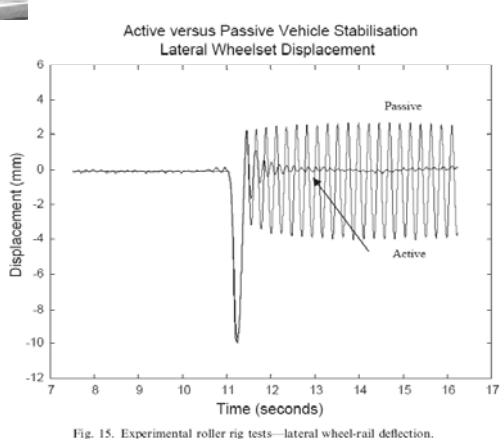


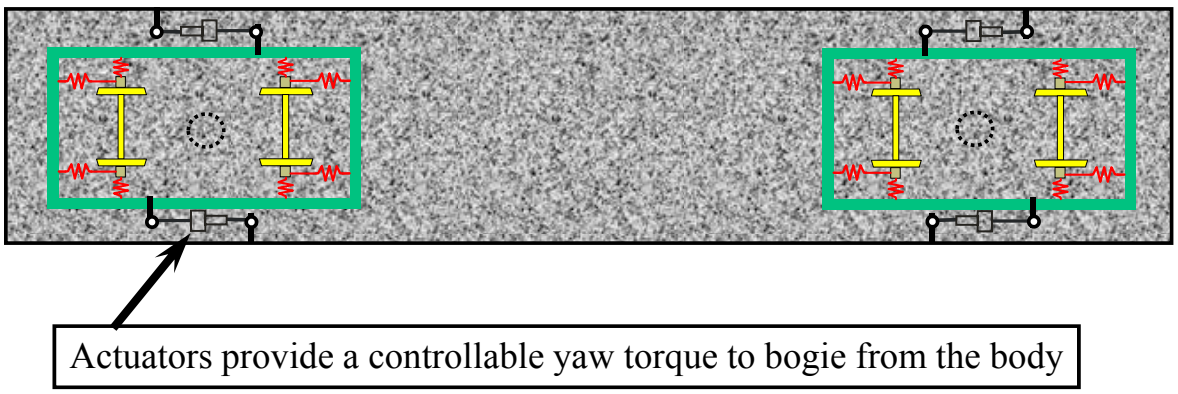
Fig. 15. Experimental roller rig tests—lateral wheel-rail deflection.

Active steering/guidance options *

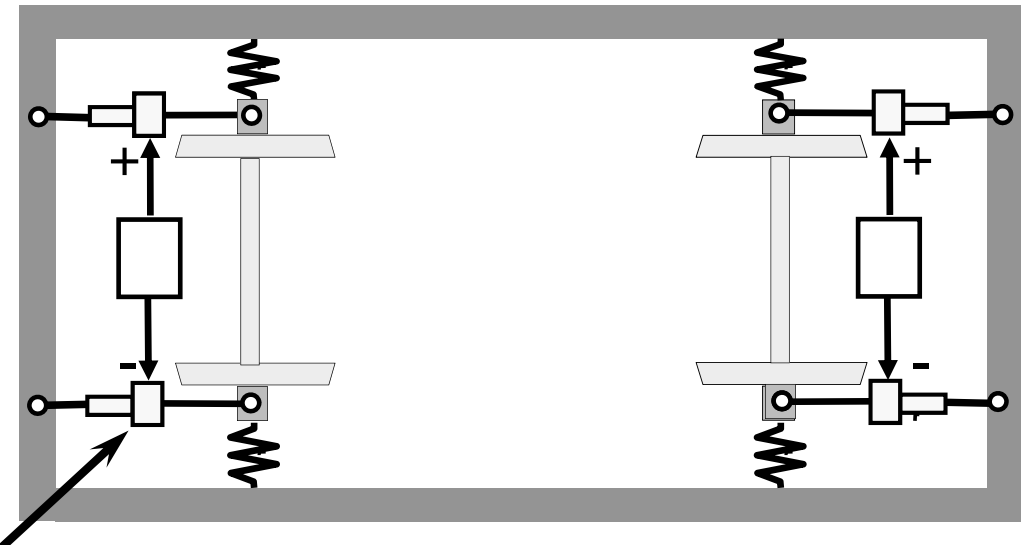
- Secondary yaw control
- Steered solid-axle wheelsets
- Steered independently-rotating wheelsets
- Independently-driven wheels
- Steered wheel pairs

* Bruni, S., **Goodall, R.M.**, Mei, T.X. and Tsunashima, H.,
"Control and Monitoring for Railway Vehicle Dynamics",
Vehicle System Dynamics, 45(7-8), August 2007, pp. 743-779

Secondary Yaw Control (SYC)

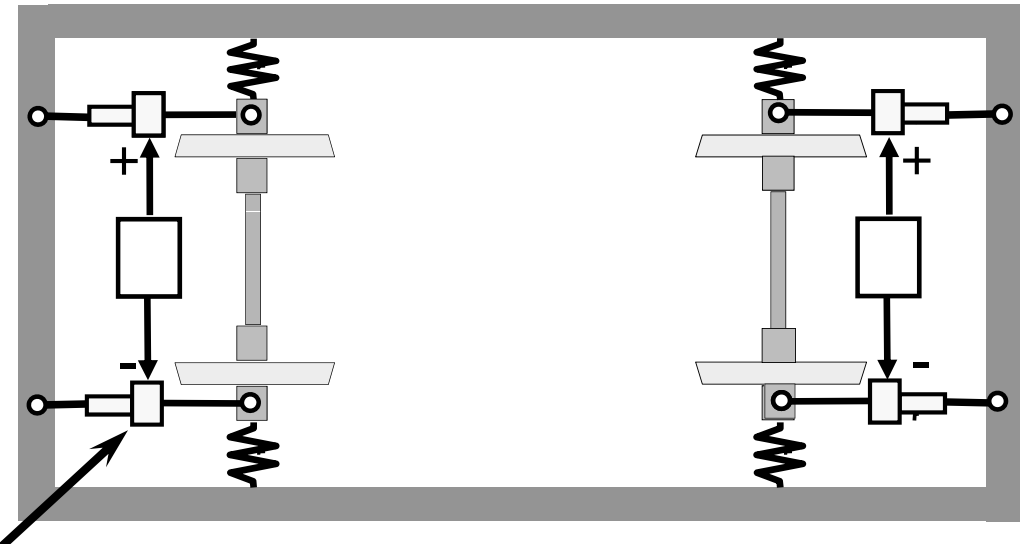


Actuated solid-axle wheelset (ASW)



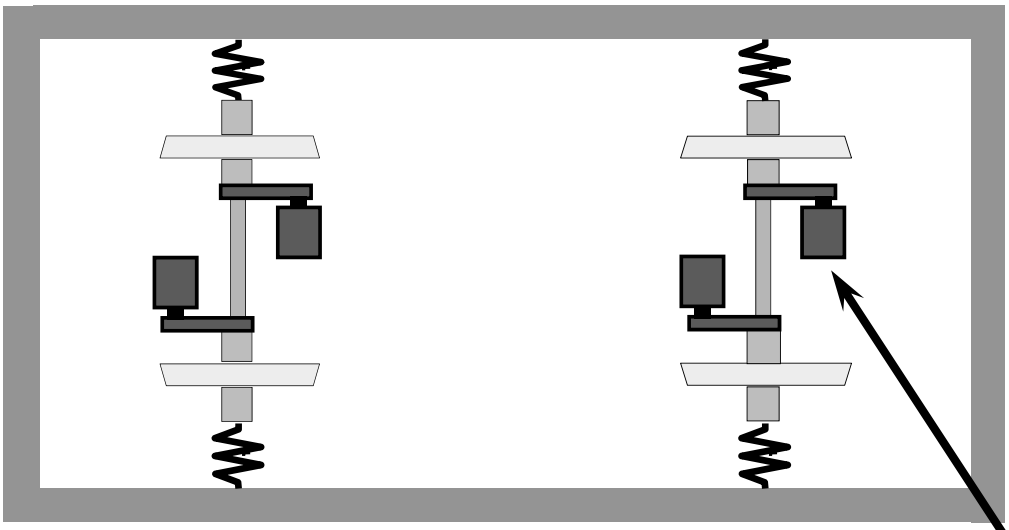
Actuators provide a controllable yaw torque from bogie to I-R wheelsets

Actuated Independently-Rotating Wheels (AIRW)



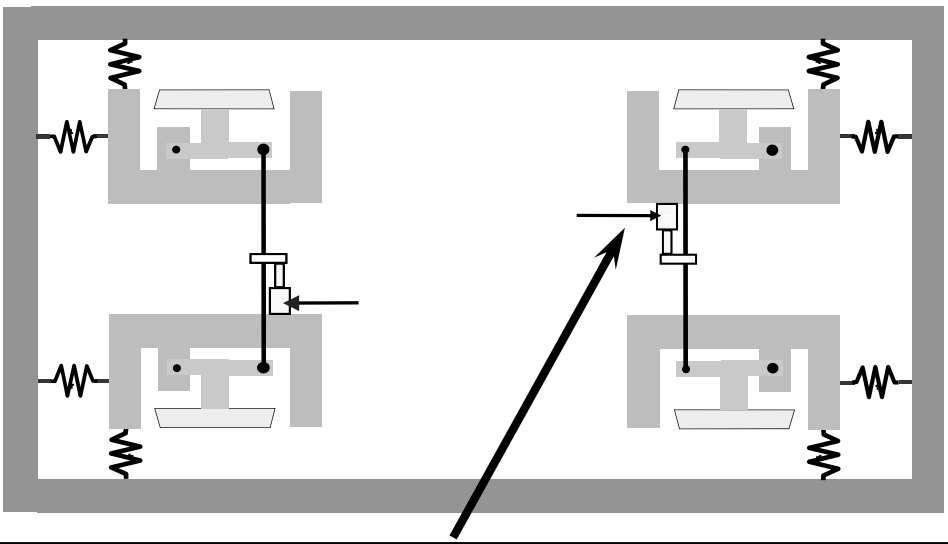
Actuators provide a controllable yaw torque from bogie to I-R wheelsets

Driven Independently-Rotating Wheels (DIRW)



Independently-driven IRWs provide drive and guidance via motor control

Directly Steered Wheels (DSW)



Mechanically similar to the front wheels of a car, but with active steering

Active steering/guidance control – potential impacts

For the vehicle:

- Important improvements to vehicle dynamic performance
- Enhanced stability
- Less wheel wear and curve squeal

For the system:

- Potential to eliminate all the "unnatural" wear of rails
- Facilitate mechanically-simple lightweight trains

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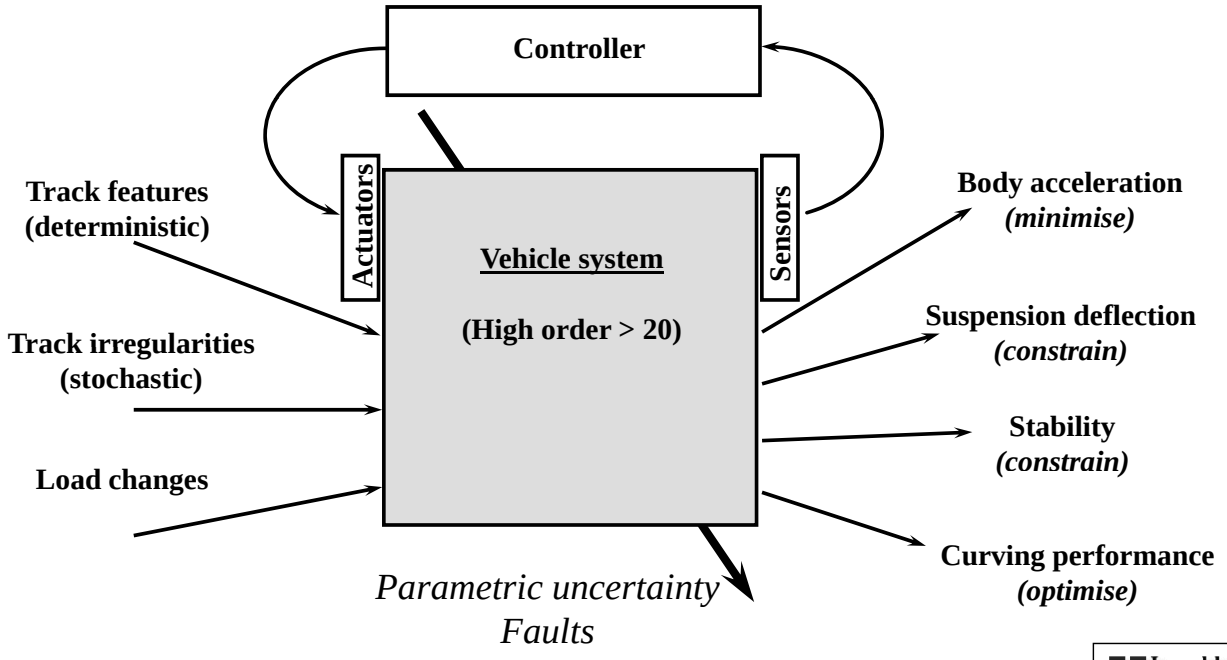
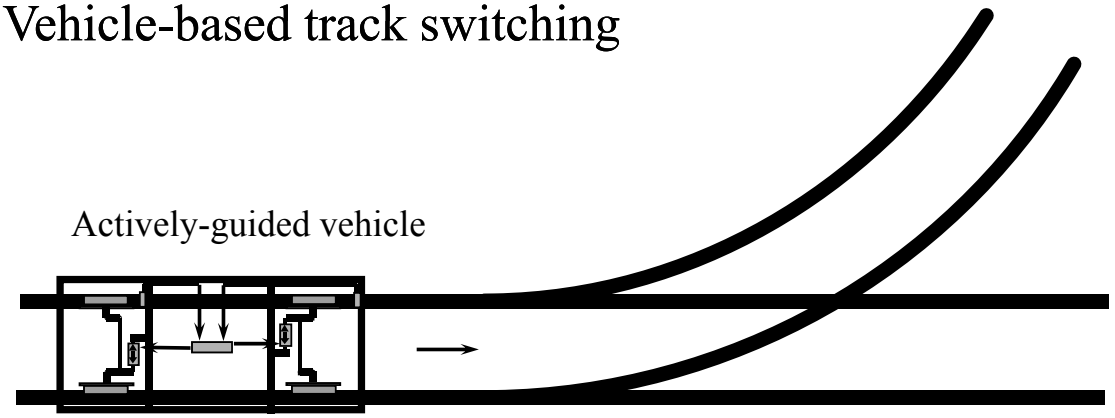
Research challenges – controller design



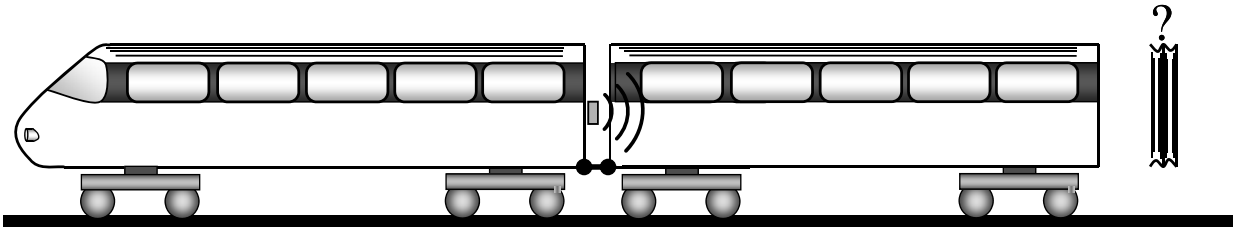
Combine …

Vehicle-based track switching



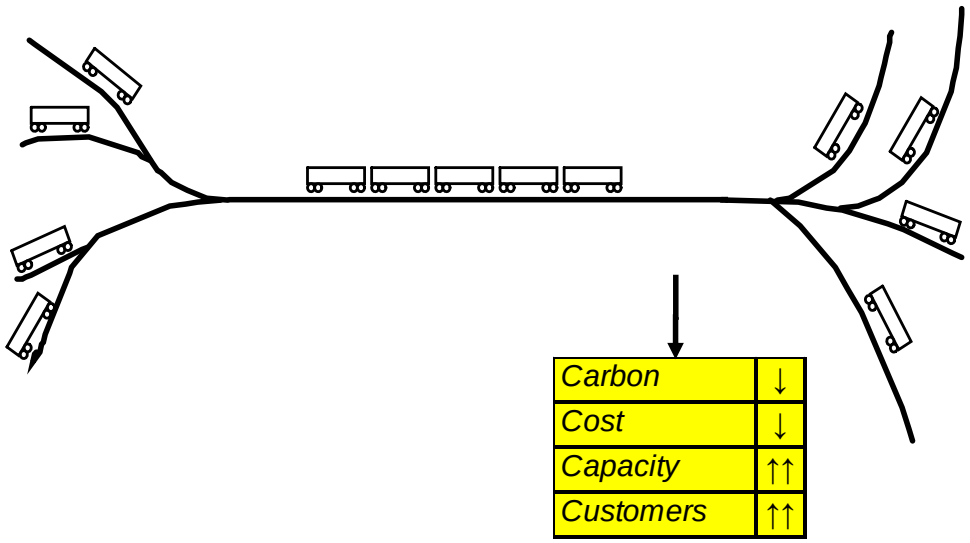
… and …

Electronic couplers



… gives …

Trains of the Future?



Control engineering research

Opportunities

- Active suspensions/running gear
- Traction system integration
- Improved current collection
- (Advanced condition monitoring)

Challenges

- Optimising the mechanical/control configuration
- Achieving affordable fault tolerance
- System-level optimisation?

Conclusions

- Major technological issues
  - Power sources and storage
  - Low impact vehicles
    - » *suspension technology*
    - » *lightweighting*
  - Advanced condition monitoring systems
- System-level issues
  - How much is it worth spending on rolling stock …
    - » *to be "greener"?*
    - » *to create low impact, lightweight trains?*
    - » *to meet future passenger comfort expectations?*