Creating a high-performance testbed for multi-axle drivetrain innovation

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FLANDERS MAKE
MANUFACTURING INNOVATION NETWORK

Outline

- **What is Flanders Make**
- Test setup and intended usage
- Methodology
- Toolchain

Our mission

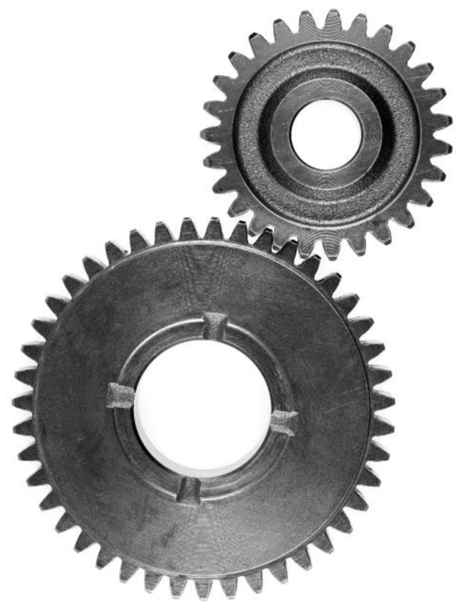
Strengthening the international long-term competitiveness

of the Flemish manufacturing industry

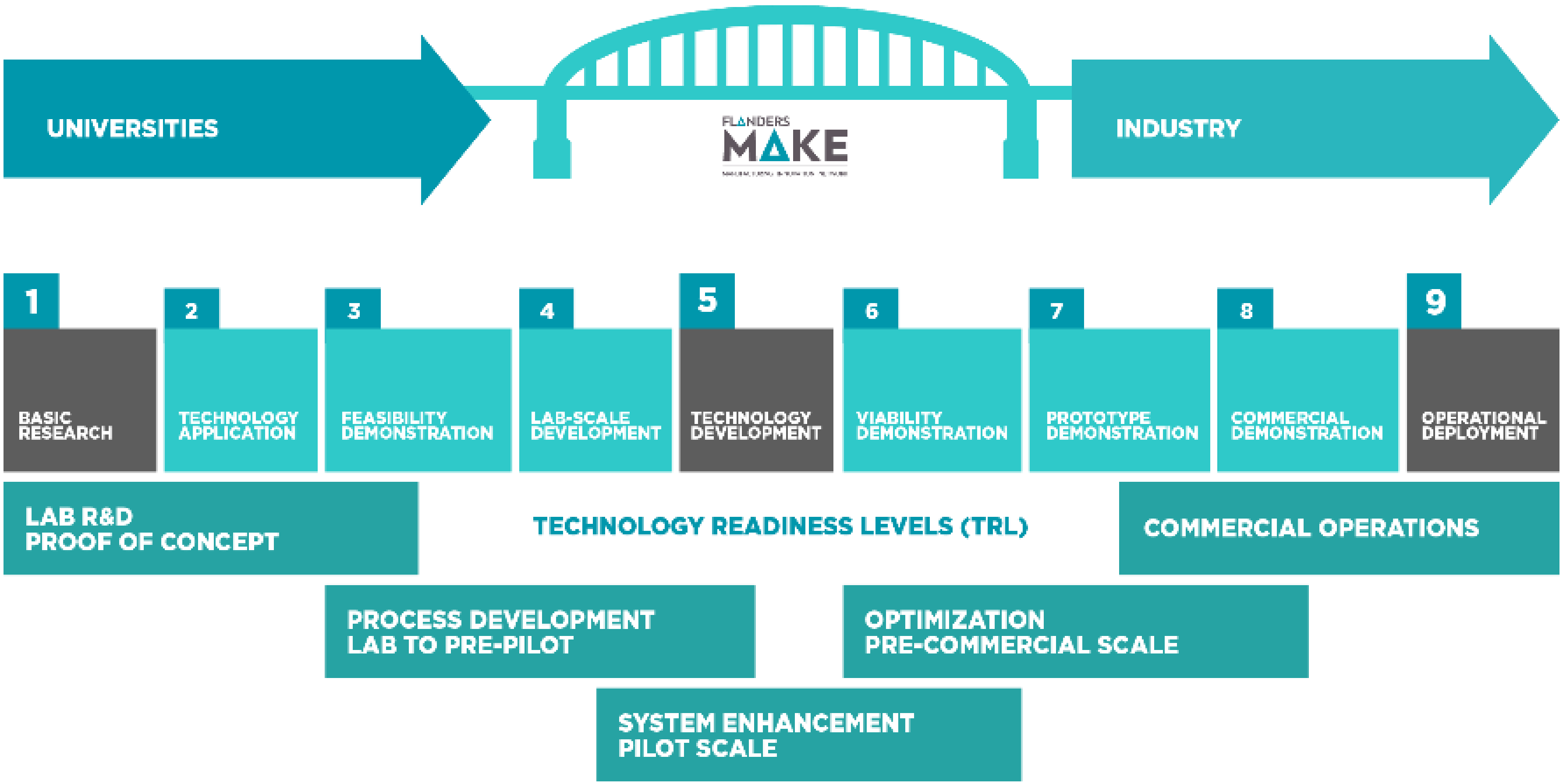
by performing industry-driven, pre-competitive, top-class research

in 2 fields of application:

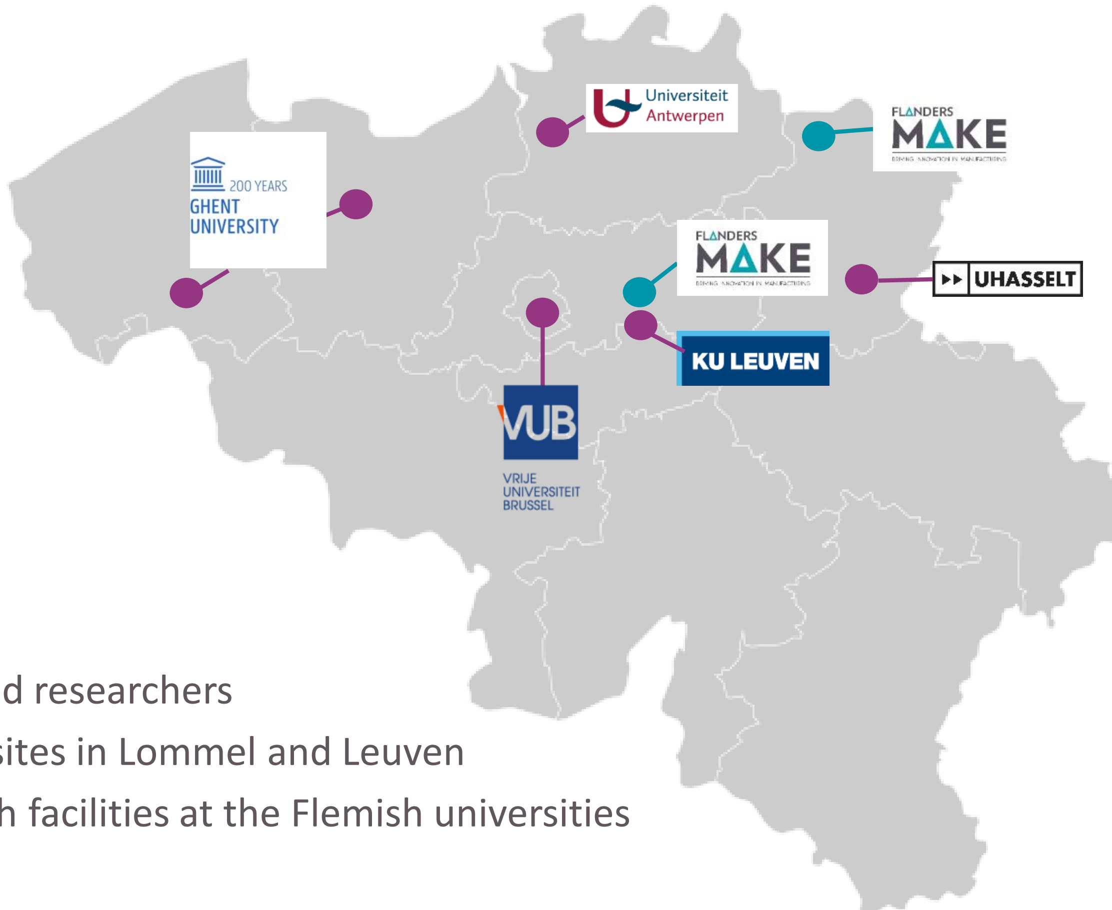
- Products: vehicles and machines
- Production: assembly plants



Innovation through collaboration



Our people

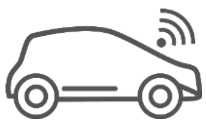


400 highly specialised researchers
operating from our sites in Lommel and Leuven
and from 10 research facilities at the Flemish universities

Large companies and SME’s

Our organisation

PRODUCTS



vehicles

machines

PRODUCTION

assembly plants

Decision & Control

Design & Optimisation

Motion Products

Flexible Assembly

Summary: Flanders Make

- Bring technology to industry
- Steer research to industrial needs

- How?
  - Joint or long term research projects
  - Consulting
  - *Test infrastructure*

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Test bed overview

- When should we use a drivetrain test bed?

- For any of the following
  - New or modified
  - Drivetrain, drivetrain component, controller, …
  - For which we want to test feasibility, tune, validate, evaluate, demonstrate …

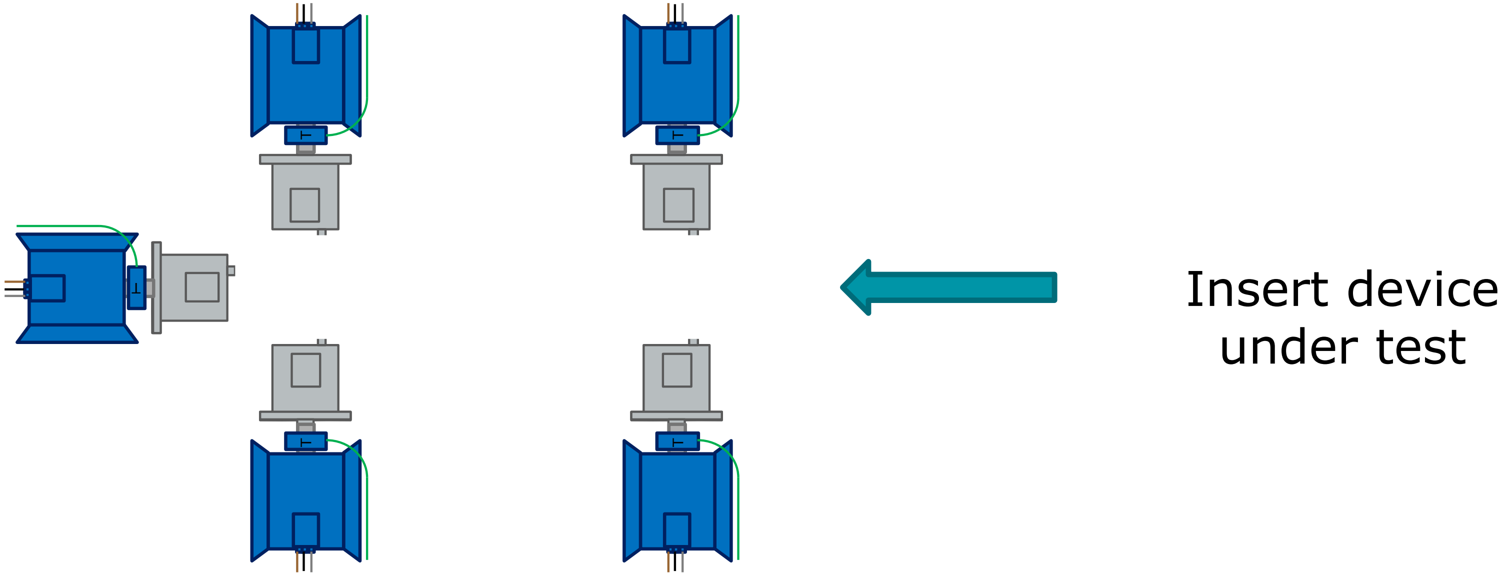
Test bed overview

- Why use a test bed at all?
  - Easier than testing on real machine
    - No need for full physical prototype
    - Improved observability – better instrumentation – improved measurement
    - Much more repeatable conditions
    - Quicker, cheaper and more energy efficient
  - Much more realistic than simulations (also more difficult)
    - Test on real physical system
    - Possibly also with real physical controller

→ Step before deployment

Test bed overview

- What is available at our test bed
  - Test infrastructure
  - To faciliate future drivetrain innovations
  - Of ourselves and others
  - Which can be flexibly adapted

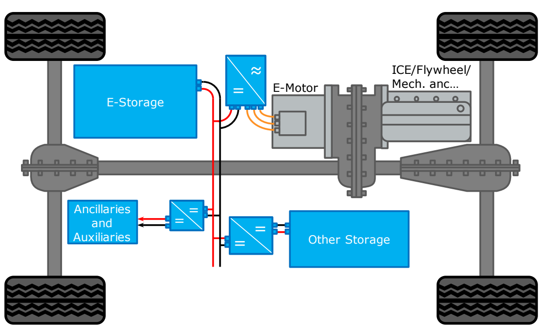


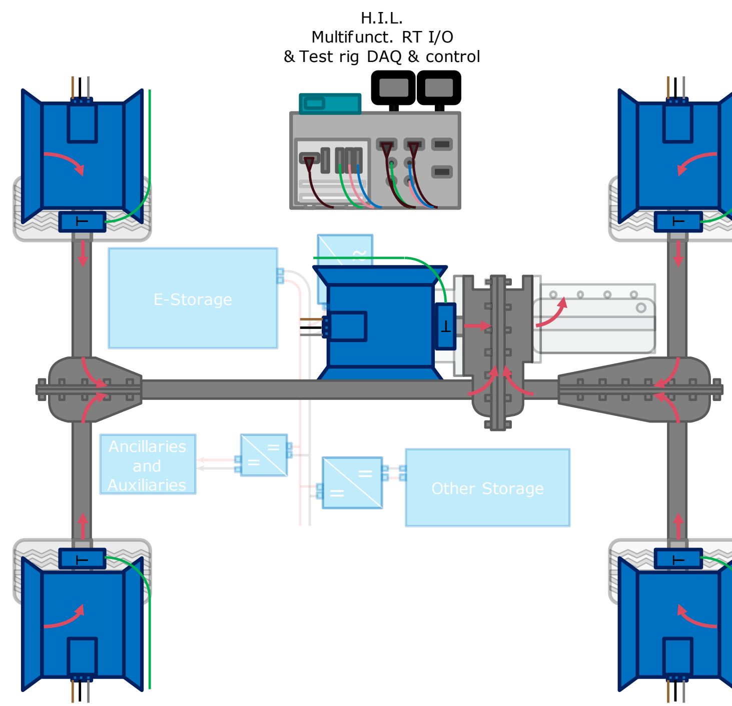
Test bed overview

- Multifunctional Drivetrain test facility
  - Motors, drives, sensors, cooling units, …
  - Interfacing and software toolchain

Example of test bed usage

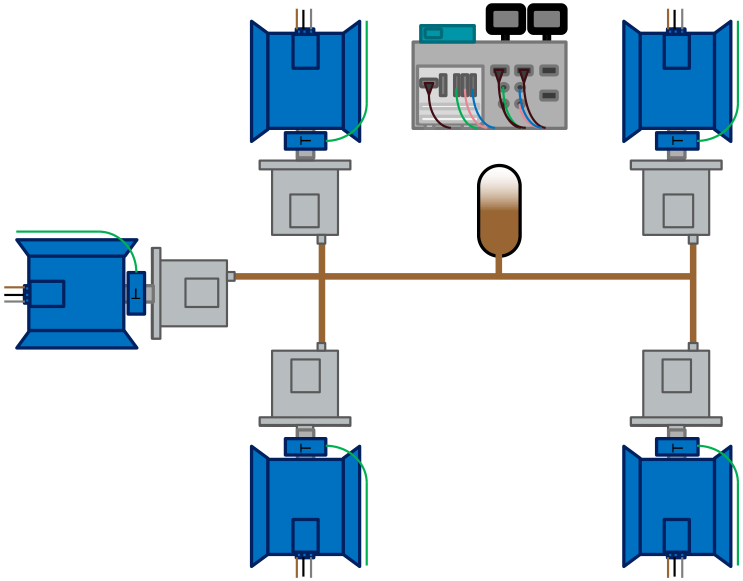
- Hybrid or regular drivetrains
- Automotive or off-highway/heavy duty





Example of test bed usage

- Mechanical, hydrostatic, hydraulic, pneumatic drivetrains
- High powers, low speeds, high torques
- Power take-offs other than wheels as well



Test bed: Overview

- Multifunctional Drivetrain HIL test facility
  - Heavy duty mobile and machine applications
  - Complex multi-axle drivetrains or their components
  - 100-500 kW applications
  - CNH, DANA, MVDW, HTI, eTrucks, VDL, MVDW, Mazaro, SISW, …

- Intended usage
  - Feasibility studies
  - Development and evaluation of controllers
  - Drivetrain topology evaluation
  - *Usage by internals, partners, externals*

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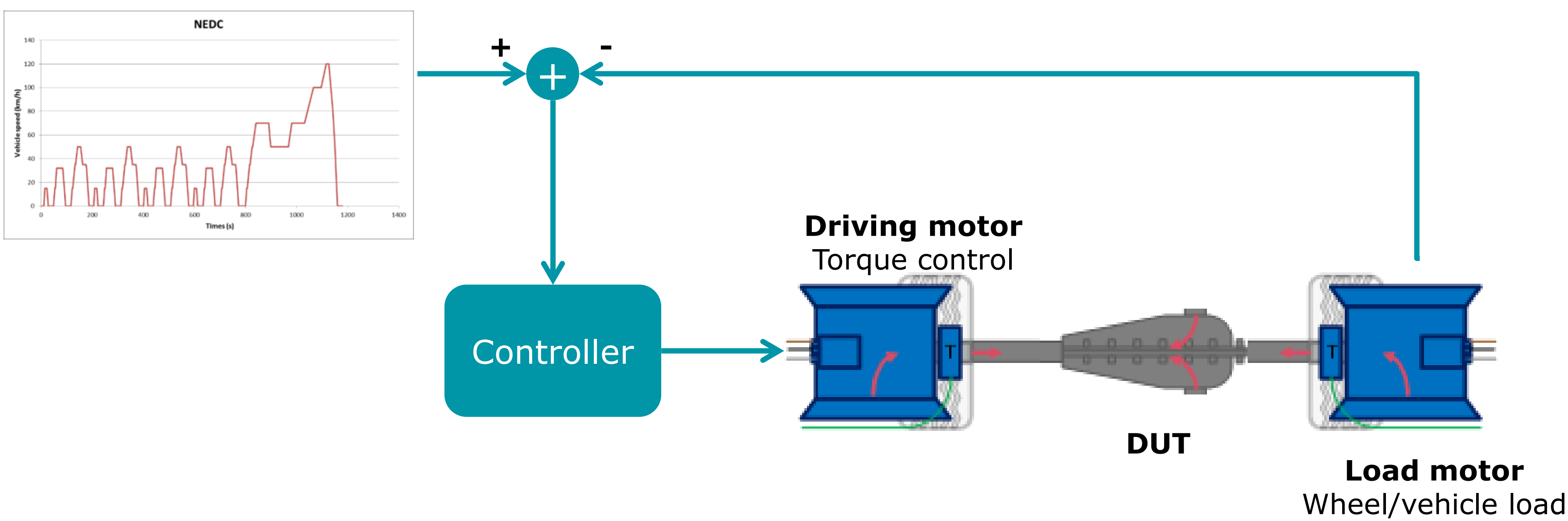
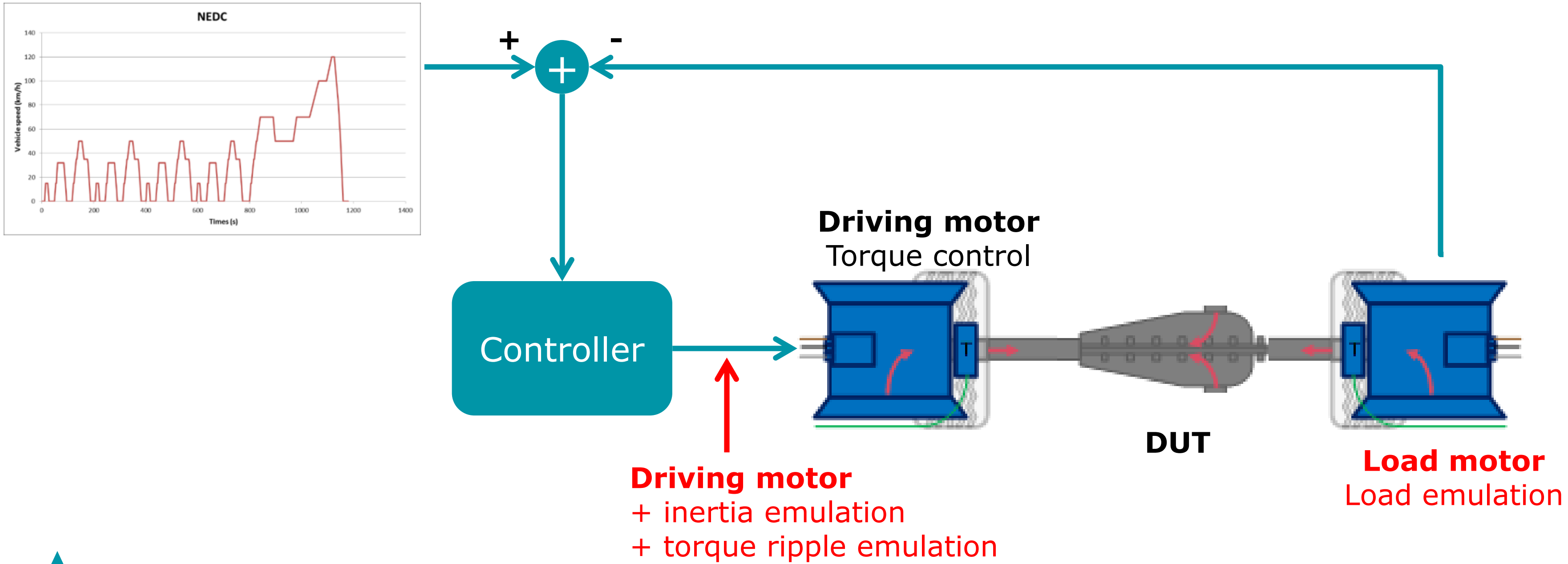
How to test drivetrains?

- Test data typically defined by vehicle speed/displacement
  - Accurate control (more repeatable) ⇔ soft control (driver-like)



How to test drivetrains?

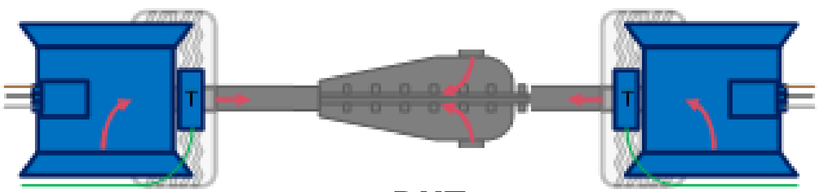
- Simply having output run at desired speed not good enough
  - Emulate vehicle inertia, wheel slip, drag torque, …
  - Sometimes also needed to emulate ICE and its torque ripple



Methodology for testing

- High bandwidth feedback needed
  - Repeatability of tests
  - Emulation of inertia, friction, torque ripple

Component	Inertia
Flywheel (dominant ICE inertia)	0.063211 kgm2
Driveshaft	0.0065845 kgm2
Tire inertia	>0.5 kgm2
PMSM inertia	**0.457 kgm2**



Driving motor
Speed control

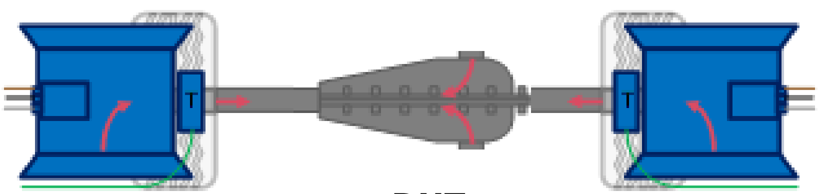
DUT

Load motor
Load emulation - **FB**

- *Difficult control problem → Intrinsically unstable with normal feedback*

Methodology for testing

- Improved approach: **Iterative learning control**
  - Learn the correct load behavior from previous experiments
  - Resulting in feedforward emulation
  - No stability issues, at cost of convergence needed



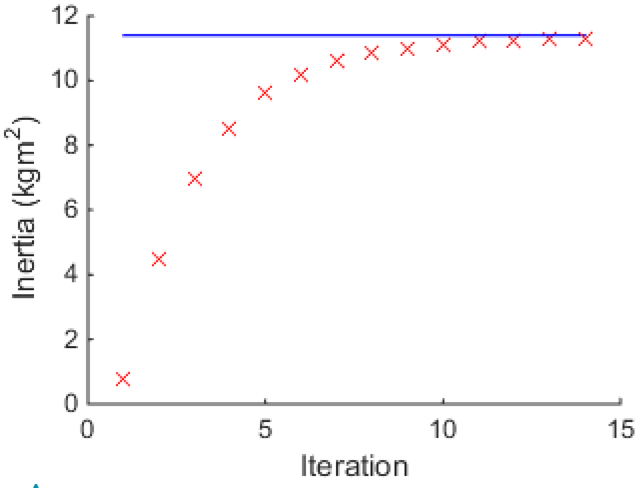
Driving motor
Speed control

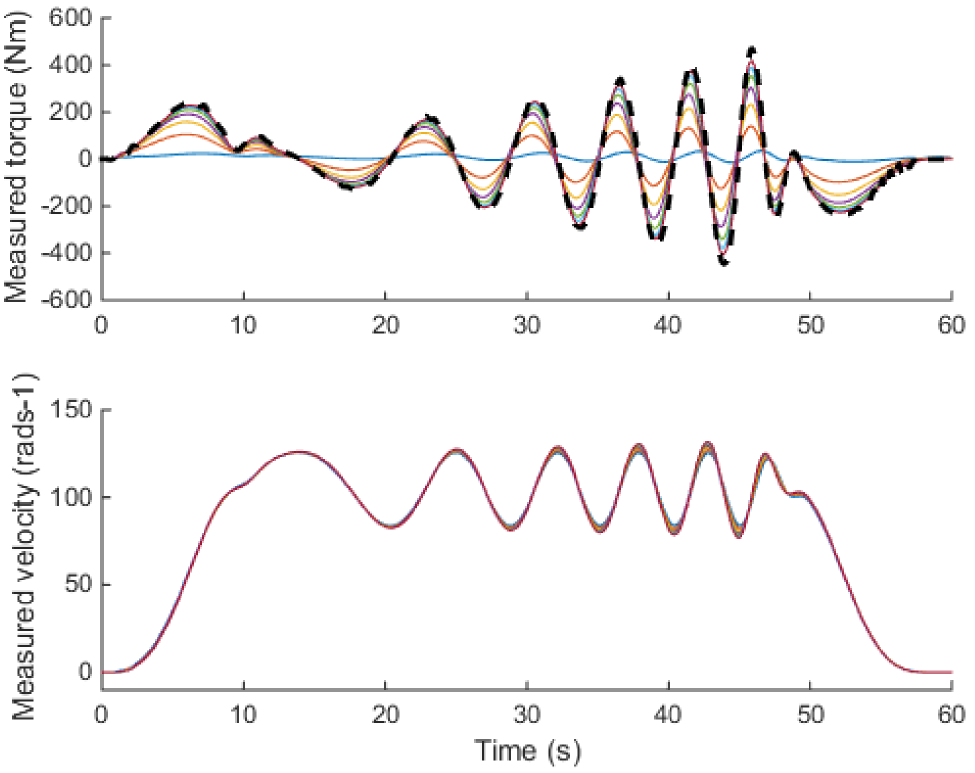
DUT

Load motor
Load emulation - **ILC**

Methodology for testing: results

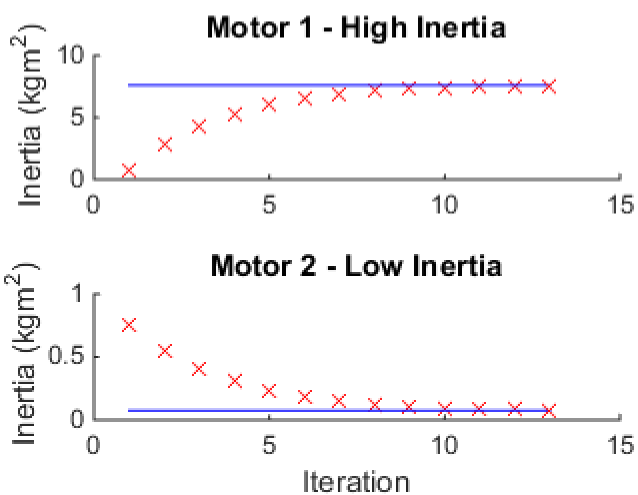
- Results for load motor emulation
  - Real inertia: 0.75 kgm^2
  - Emulated inertia: 0.75*15 = 11.5 kgm^2
- Good emulation after **10 trials**

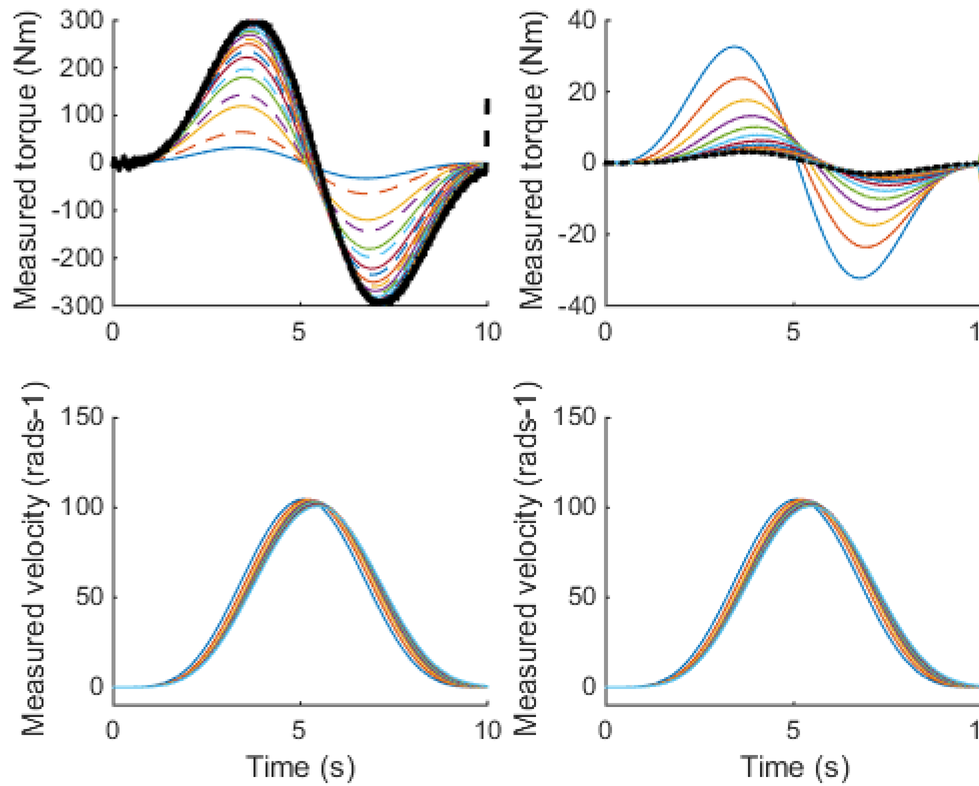




Methodology for testing: results

- Results for driving *and* load motor emulation
- One higher one lower
- Still good emulation after **10 trials**





→ **Repeatable tests**
→ **Stable broadband emulation**

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Toolchain

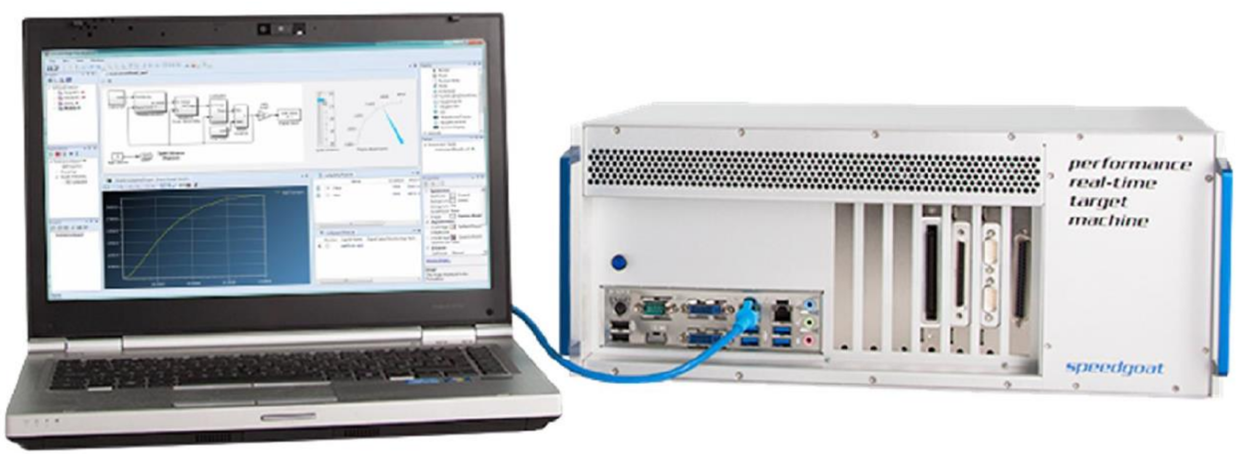
- What kind of toolchain do we use?
  - Interfacing motors, sensors, …
    - But also DUT controllers, new sensors, …
  - Quick and flexible software
    - Define controller for DUT
    - Emulate load, emulate inertia, …
  - Interactive operation, logging, debugging, …

→ Modular I/O

→ Automatic codegen from MATLAB/Simulink

→ Rapid-prototyping environment

- Solution: Speedgoat system + MATLAB + Simulink Real-Time



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Conclusion

- Flanders Make test bed
  - For various types of drivetrains
  - Accurate load emulation and repeatable tests
  - Easy to use toolchain
- Available and ready for use

Is it relevant for you?

- Yes … if you are in need of
  - Realistic physical testing
  - Of new/modified controllers, components, drivetrain topologies
  - Under repeatable and accurate conditions
  - With additional sensing
  - Efficient to set up and reconfigure