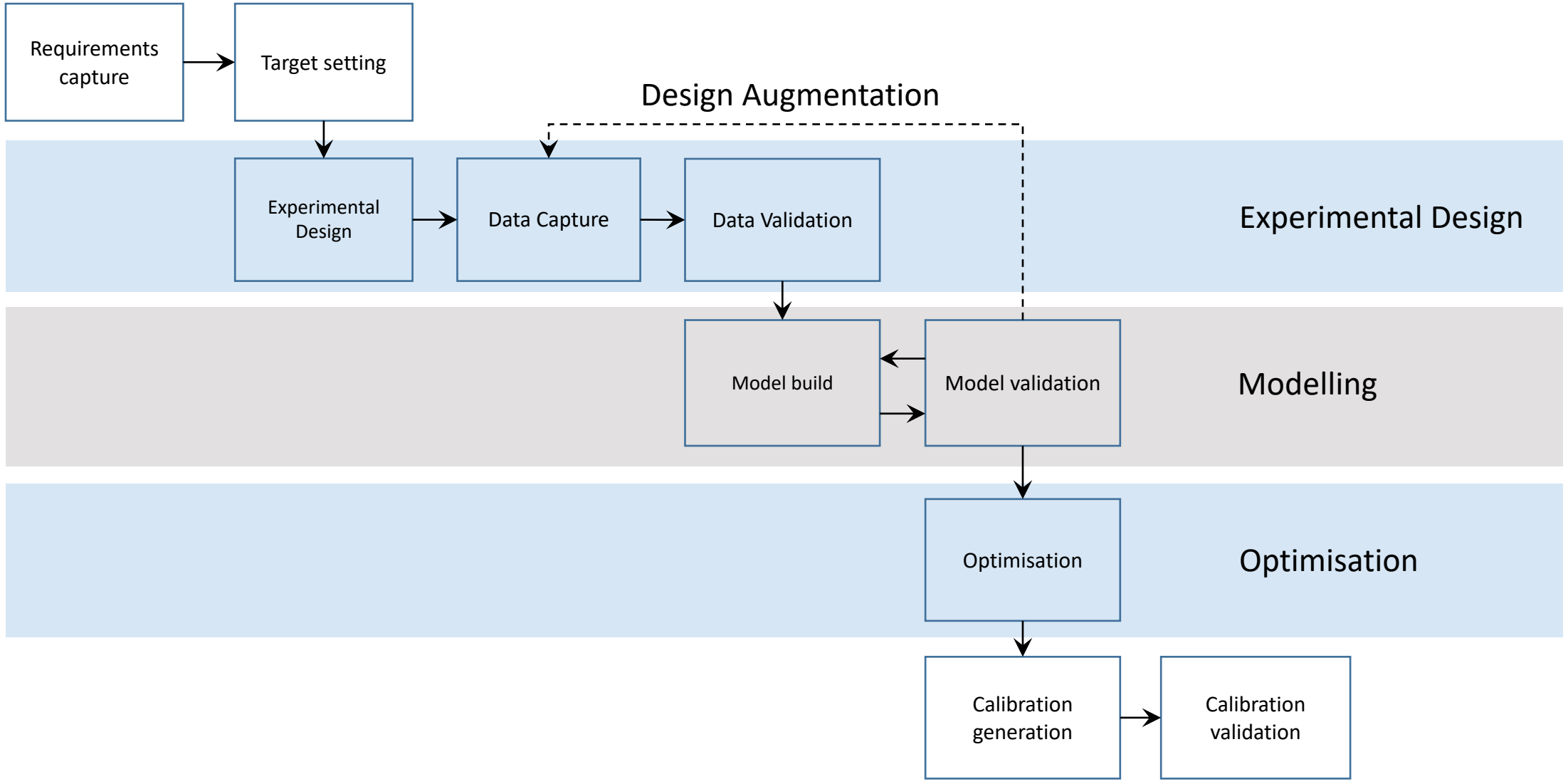
Powertrain Calibration Optimisation

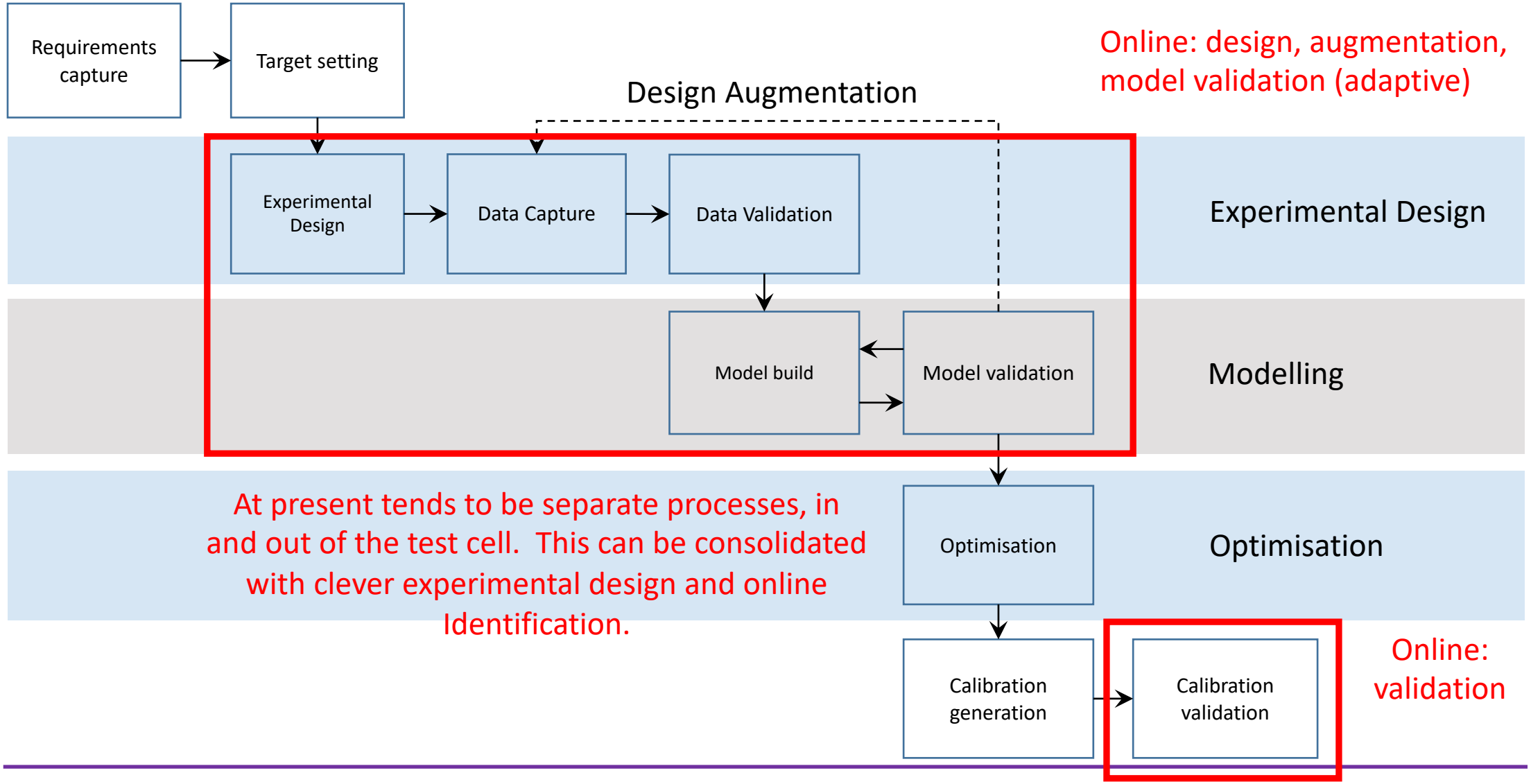
Future Trends In Calibration

What is the future for calibration?

Powertrain Calibration Optimisation



Powertrain Calibration Optimisation



Trends in the Calibration Process (1)

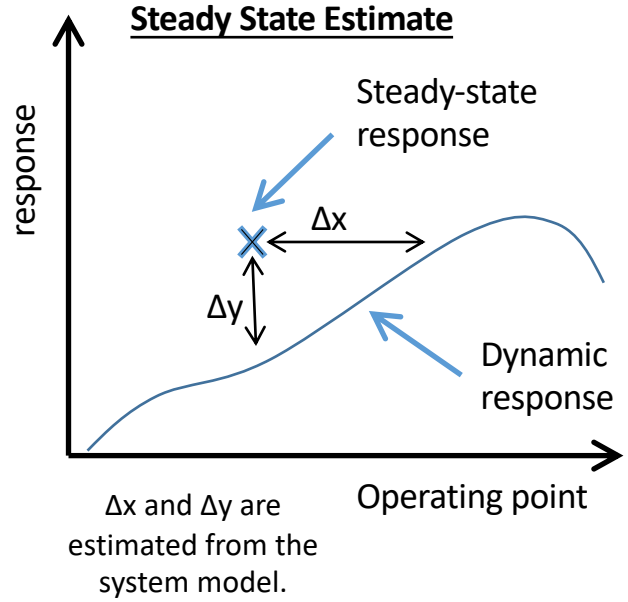
Improving engine test efficiency

- Integrating prior knowledge into the DoE process
  - Bayesian
  - Adaptive design
- Model (white and grey) based calibration
- Taking data more efficiently
  - Excitation signal design
  - Using transient tests
  - Using reference models

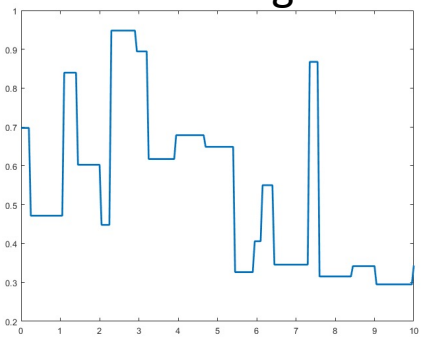
} More test? More significance.

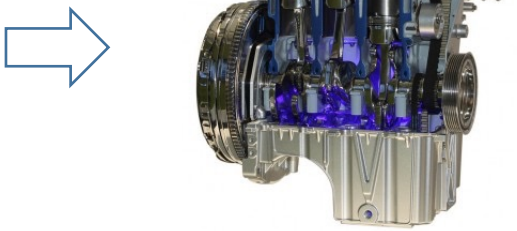
The Future

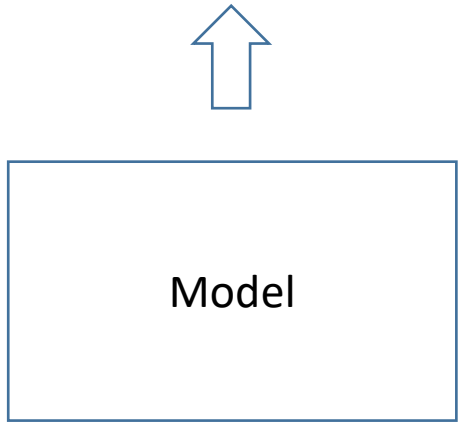
- Use of transient tests to rapidly estimate steady-state engine responses.
- Models running at the same time as testing (online) are used to;
  - Compensate for test system dynamics.
  - Determine optimal test path and establish test control.
  - Estimate system steady-state responses.



AMPRBS Signal

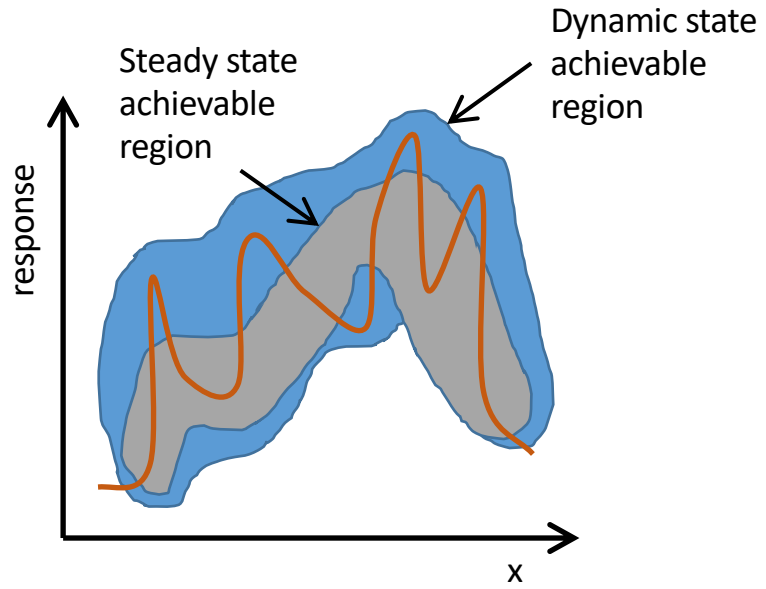






The Future

- Significantly reduced test time.
- More information about the system.
  - Additional system states achievable.
  - Dynamic models for optimisation.
  - Required for characterisation of discontinuities i.e. VDE.
- Improved data efficiency.
  - Data is collected from engine-on.
  - More data is taken where needed, less where not.
  - Little/no stabilisation time.
- Data produced is more (mathematically) steady-state
  - Traditional steady-state tests are not undertaken in steady-state!
  - More repeatable data.



Ability to extend characterisation to areas of the operating space not previously possible.

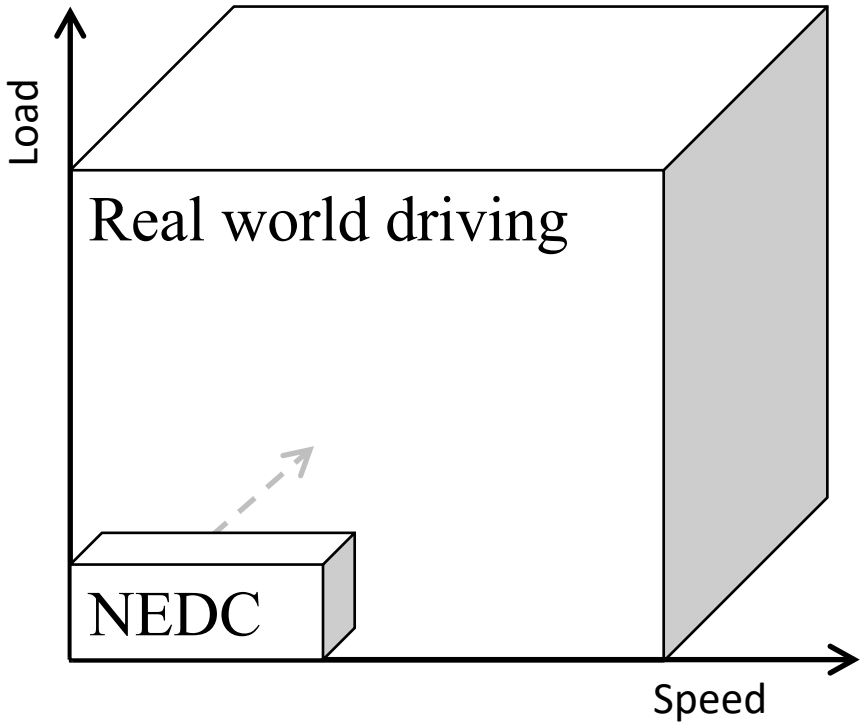
Trends in the Calibration Process (2)

Widening the scope of the test programme

- Increased ‘calibration’ space through RDE
- Transient behaviour needs to be considered more carefully (modelling and optimisation)

An integrated approach to calibration and control

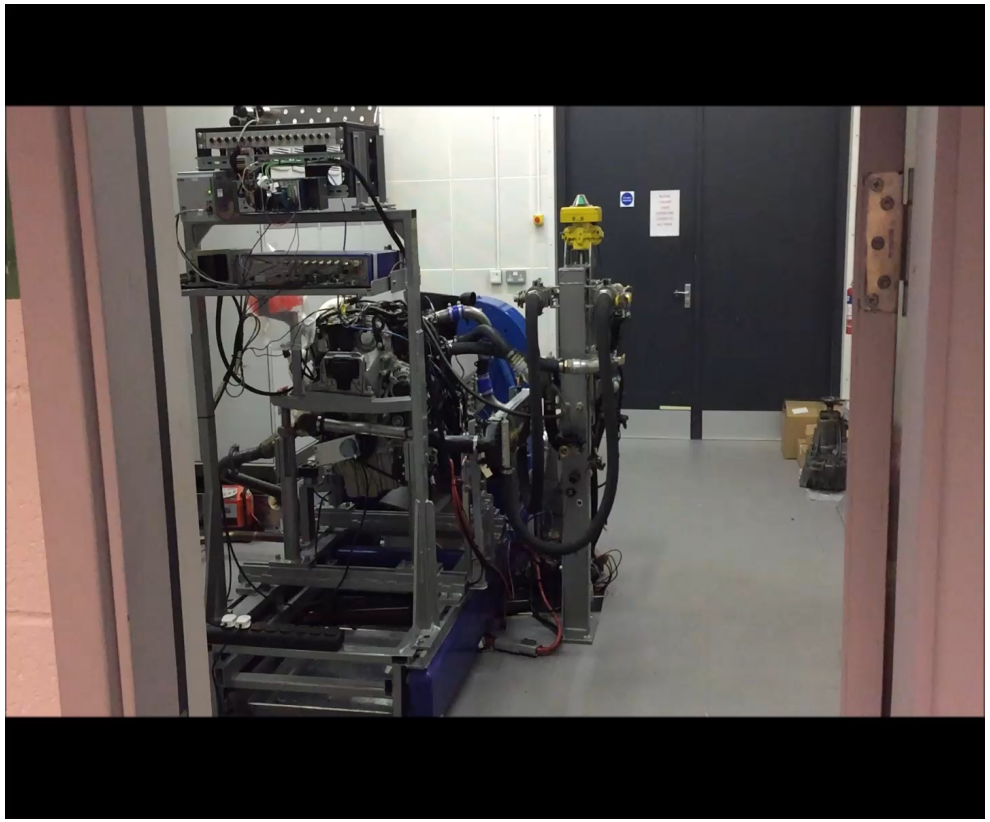
- Deliberate focus on calibration friendly control
- Multi-variable control
- More feedback?



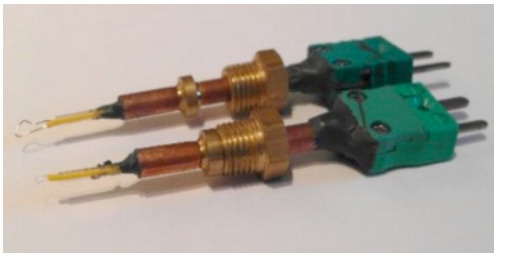
Trends in the Calibration Process (3)

Optimisation in real time in the vehicle

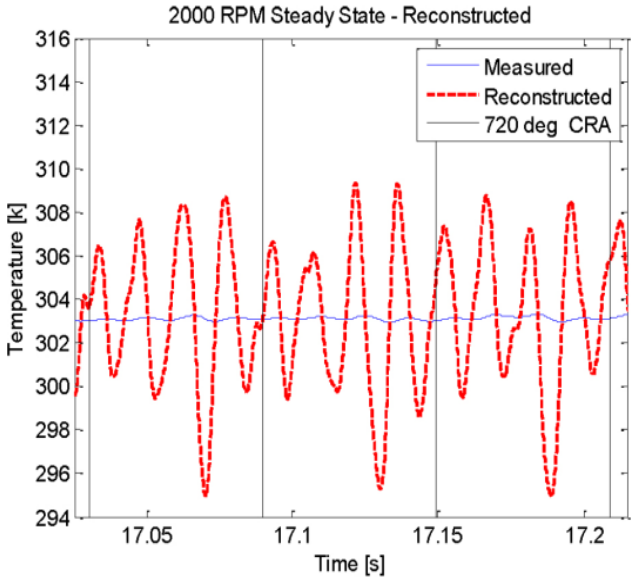
- Adaptive calibration – adaptation of existing calibration
  - Model predictive control
- Self-calibration / learning control – birthing test for engines
  - Issues for certification?
  - How to initialise the system?
  - Machine learning opportunities



Trends in the Calibration Process (4)



- Better understanding of emissions generation
  - Particulate formation and evolution
  - Use of surrogate models in development
- Use of better measurement technologies in the lab (and on vehicle)
  - Test cell observer use
  - More capable sensors
    - Fast response
    - Optical techniques
- System level (dynamic) optimisation
  - Model based calibration-optimisation (AVL *Mobeo*)
  - Working across the normal system boundaries to get better overall behaviour



Conclusions

- Global CO_2 & toxic emissions legislation & rapid development of Electrified, Autonomous & Connected vehicles will drive major technological changes & increasing complexity including Calibration
  - This presents challenges for the containability of development costs hence need for improved Development Processes
- Calibration Techniques
  - New technologies will require optimisation requiring similar approaches to emissions DOE techniques learned on course
  - Inevitably more automated processes will be introduced over the coming years to cope with the growth in technical demands and world-wide markets
- The key role of the engine calibrator is assured for many decades to come and the some of the products you'll be working on will be pretty amazing.