# One-sided cooperation between human driver and active accelerator pedal

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# Centre for Sustainable Road Freight

- A collaboration between Cambridge and Heriot Watt Universities and the freight transport industry
- Research into low carbon vehicle engineering and logistics

# Aim:

*To reduce to the energy consumption of HGVs by improving the driver's control of the accelerator pedal*

# Haptic Feedback

- Advantages:
  - Continuous support to driver
  - Doesn’t distract the driver’s vision
  - Long-term effect
- Disadvantages:
  - Must be built in to vehicle
  - Can be disliked by driver

# Project Objectives

- The potential of active accelerator pedals is not fully explored in the heavy goods vehicle application…

Objective:

*Develop a mathematical model of the driver's cognitive control of a vehicle with active pedal force*

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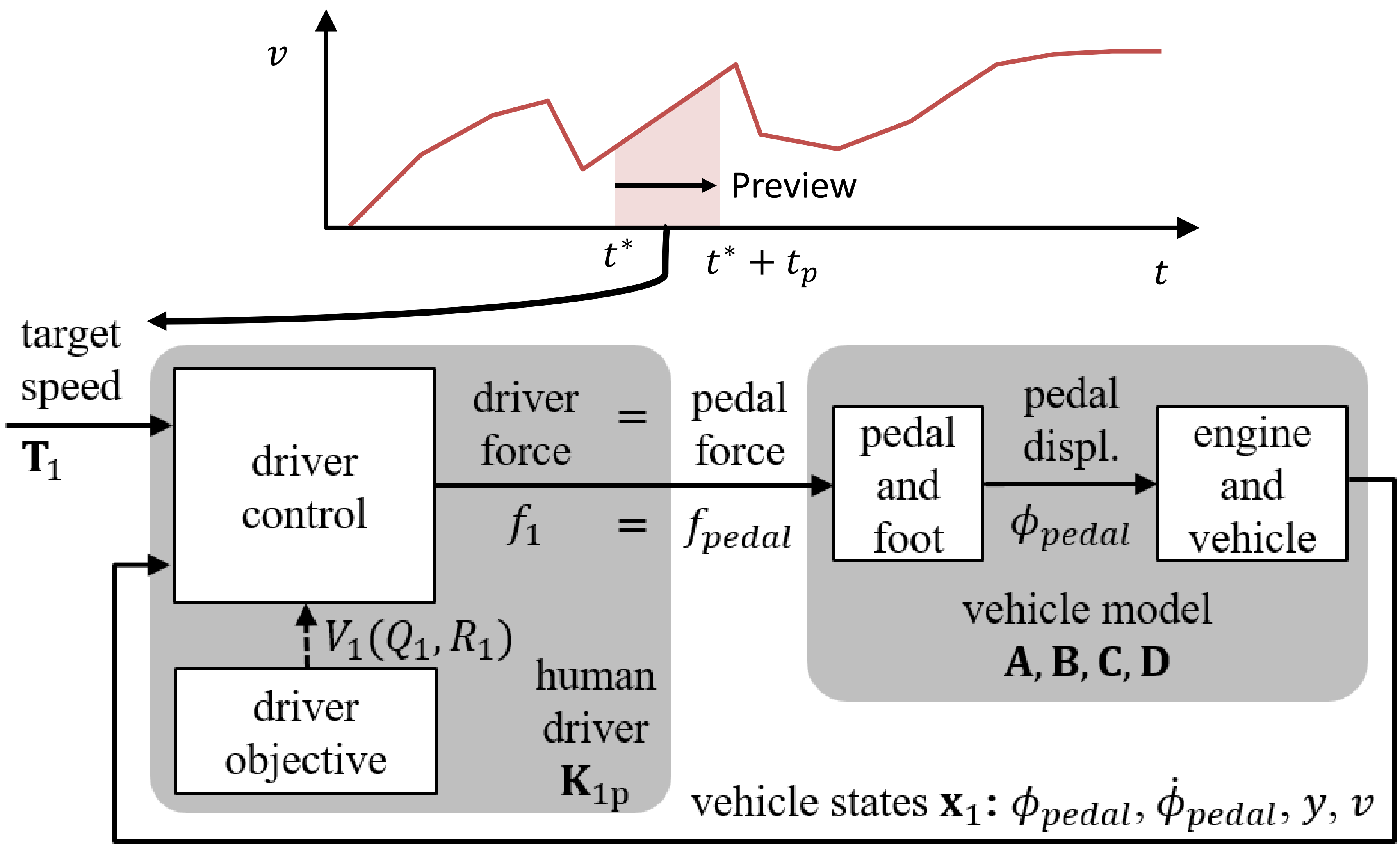
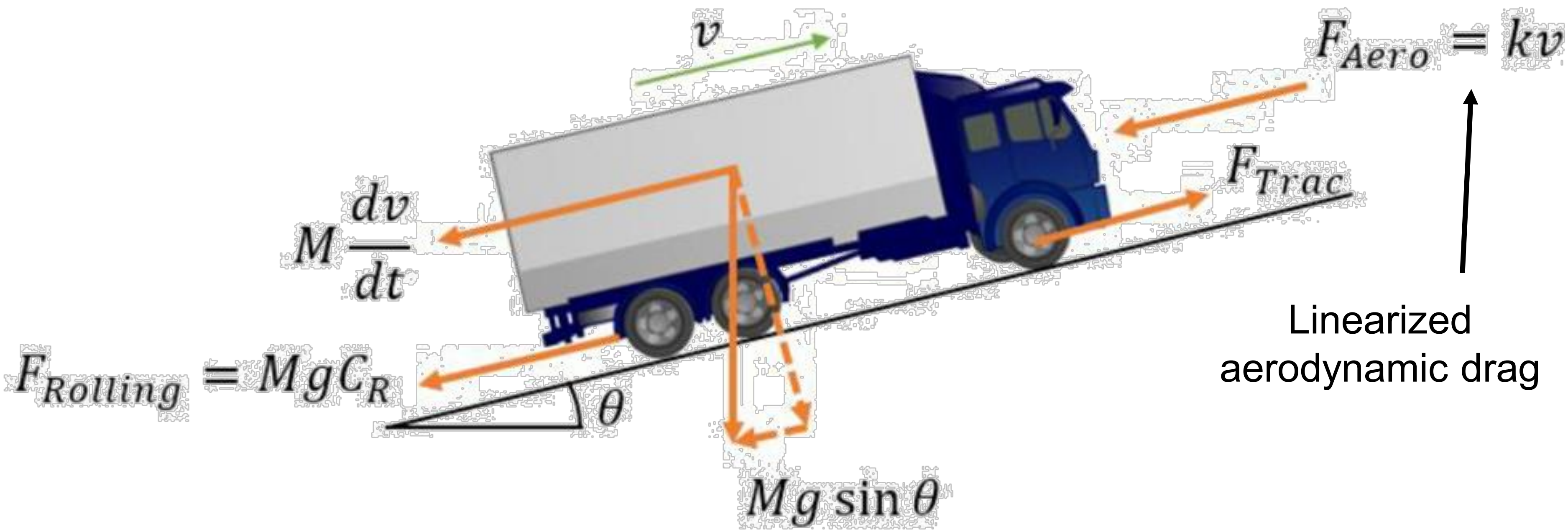
# Driver-Pedal Interaction



# Vehicle Dynamics

$$F_{Aero} = \frac{1}{2}\rho C_D A v^2$$

or




Linearized aerodynamic drag

# Optimisation

- Optimise by minimising a cost function:

speed error

$$V_1(k) = \sum_{i=1}^{N_p} q_{1v}\left(v(k+i) - r_v(k+i)\right)^2 + \sum_{i=1}^{N_p} q_{1\phi}\,\phi^2(k+i) + \sum_{i=0}^{N_p-1} {f_1}^2(k+i)$$

pedal displacement

pedal force

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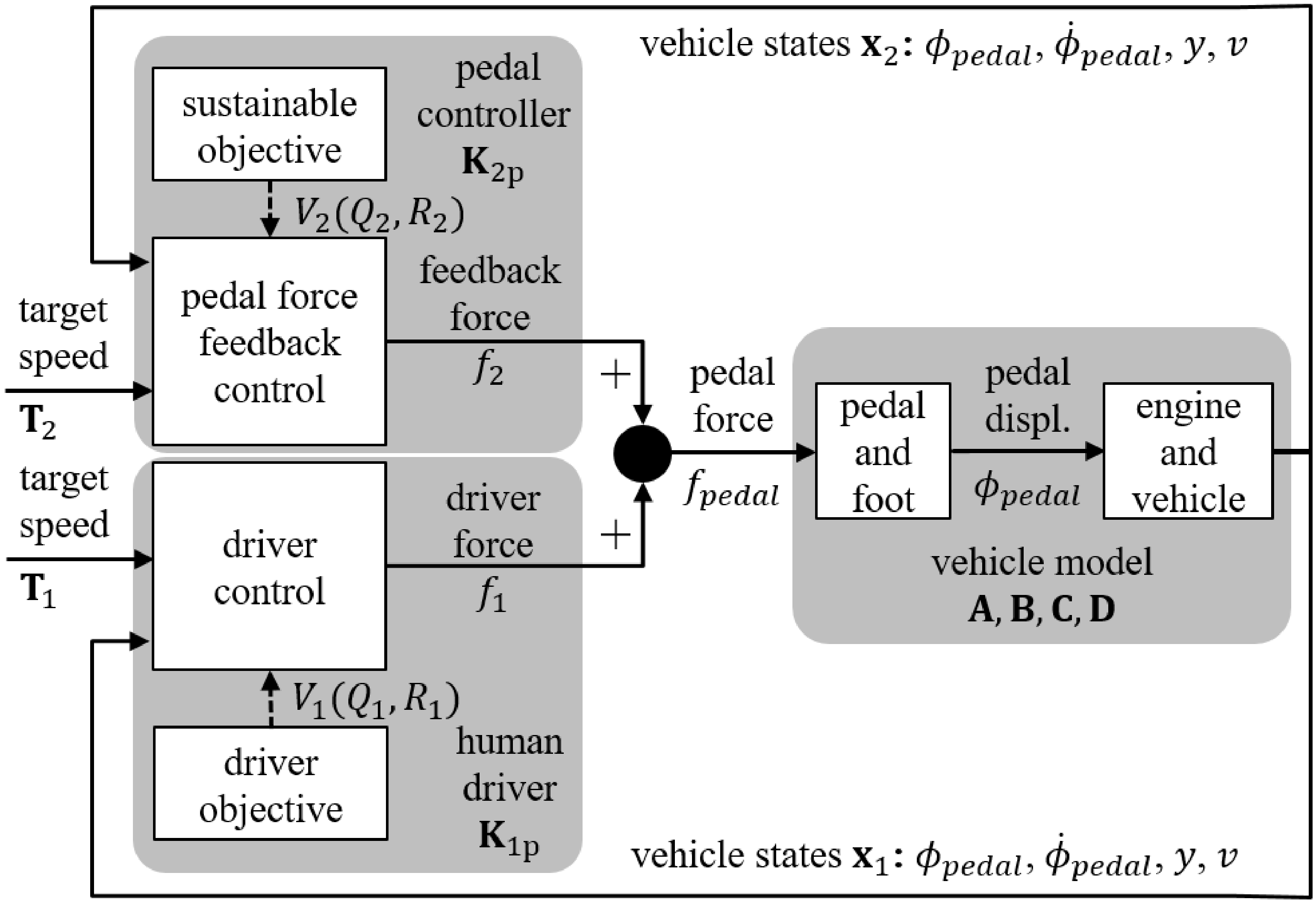
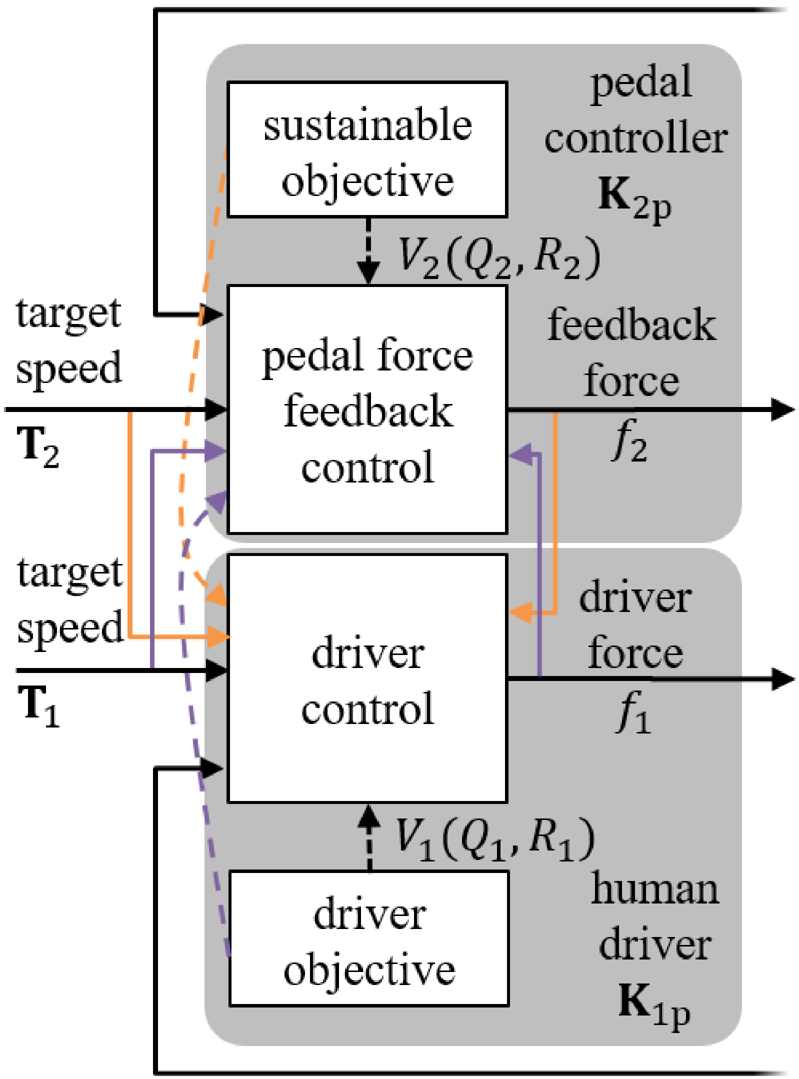
# Active Pedal Force



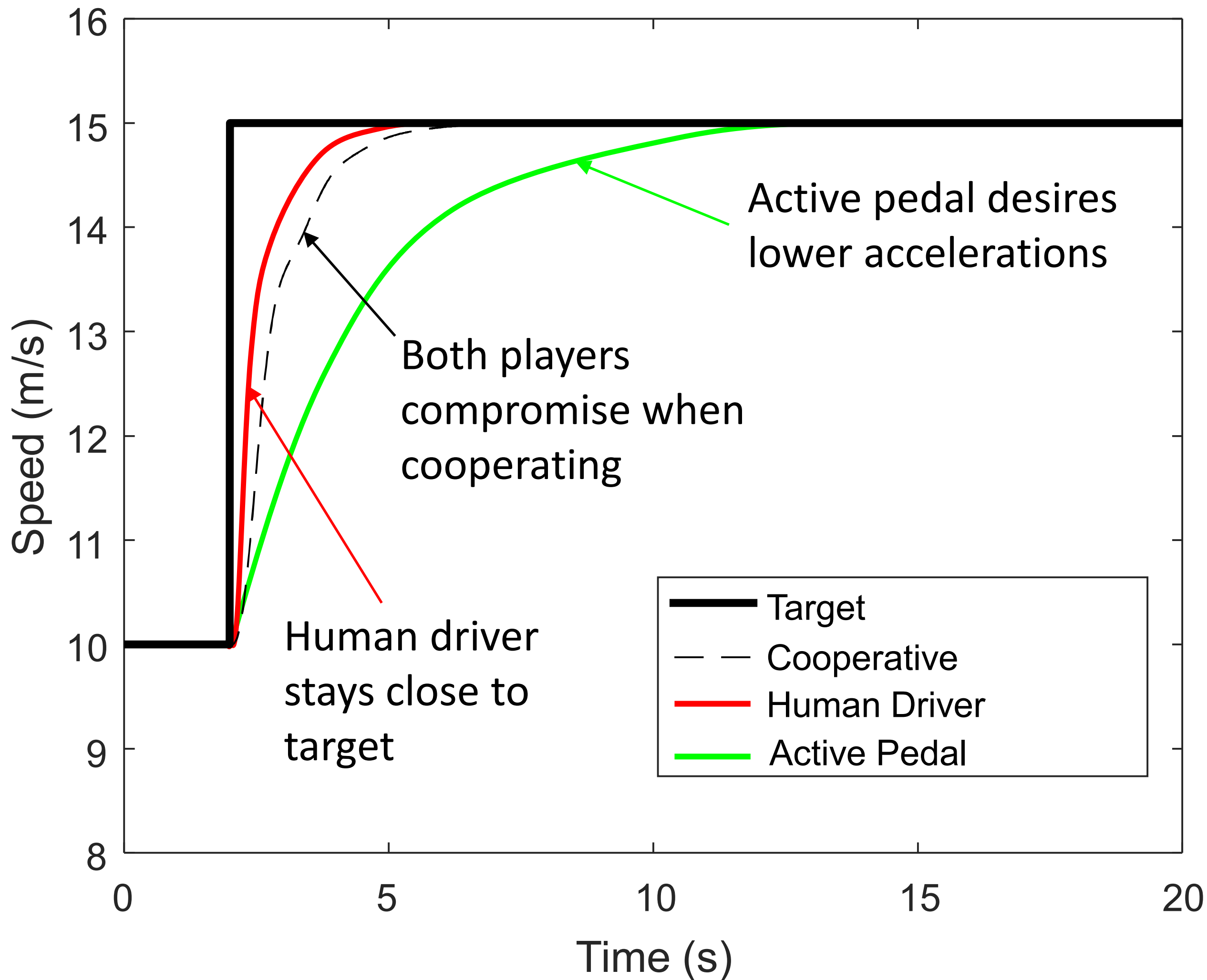
# Cooperative Control




- The driver and active pedal take each other's objective and action into account
- A 'global' cost function is defined as a weighted sum of the driver's and active pedal's own cost functions

# Cooperative Control

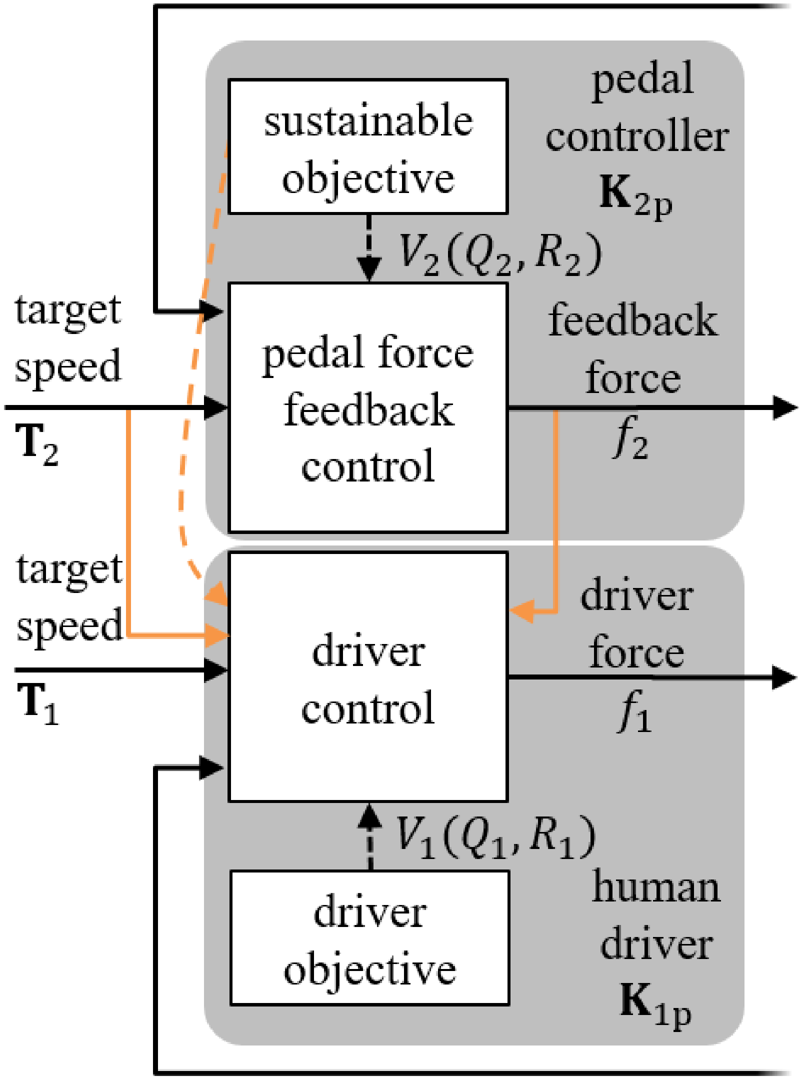
- Cooperative Control results in compromise:




Speed focussed Driver:
$q_v = 80$,
$q_\phi = 1$

Eco Active Pedal:
$q_v = 30$,
$q_\phi = 1$

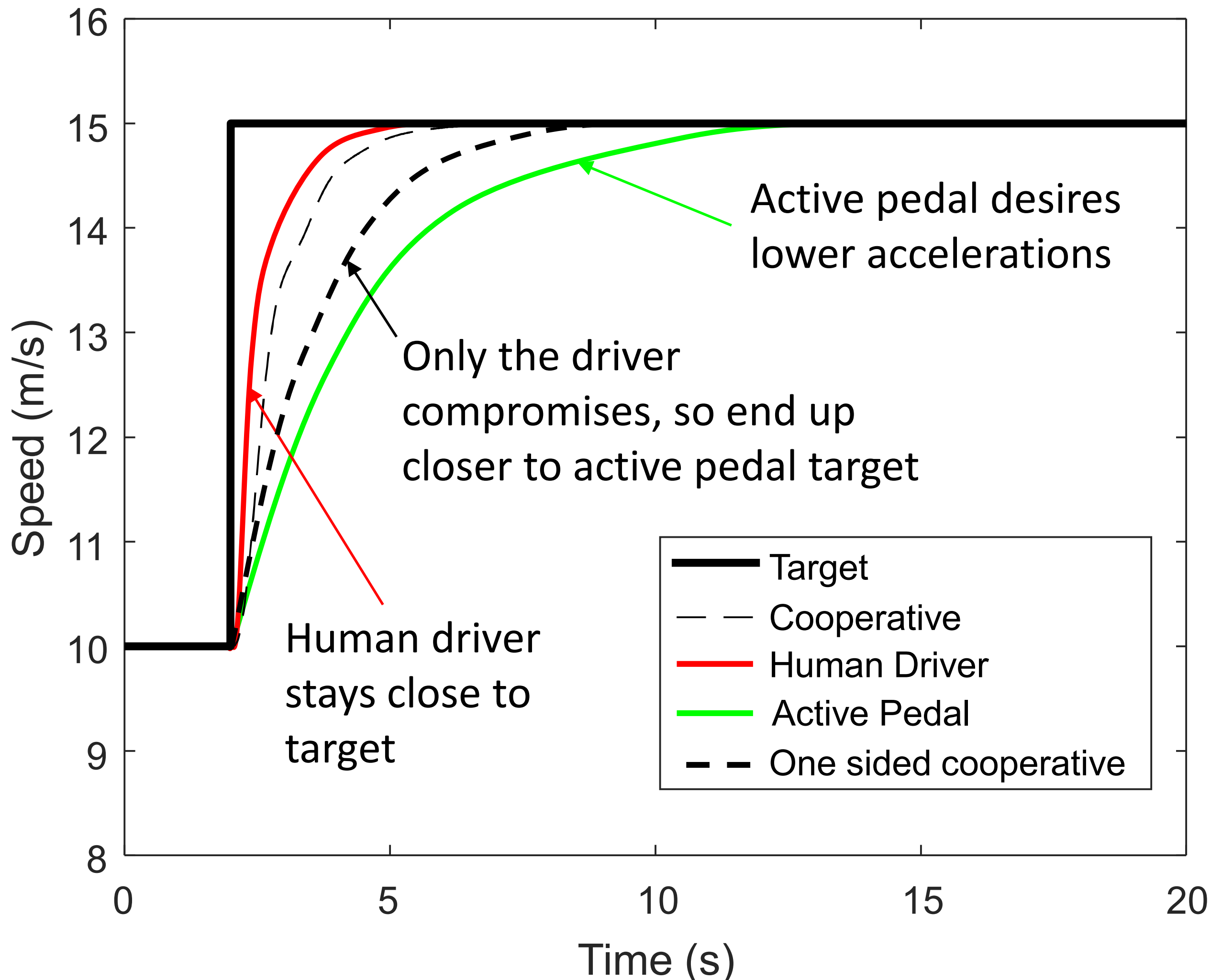
# One-sided Cooperative Control




- The driver takes the active pedal's objective and action into account
- The driver amends their cost function to a weighted sum of the driver's and active pedal's own cost functions

# One-Sided Cooperative Control

- Only the driver compromises:



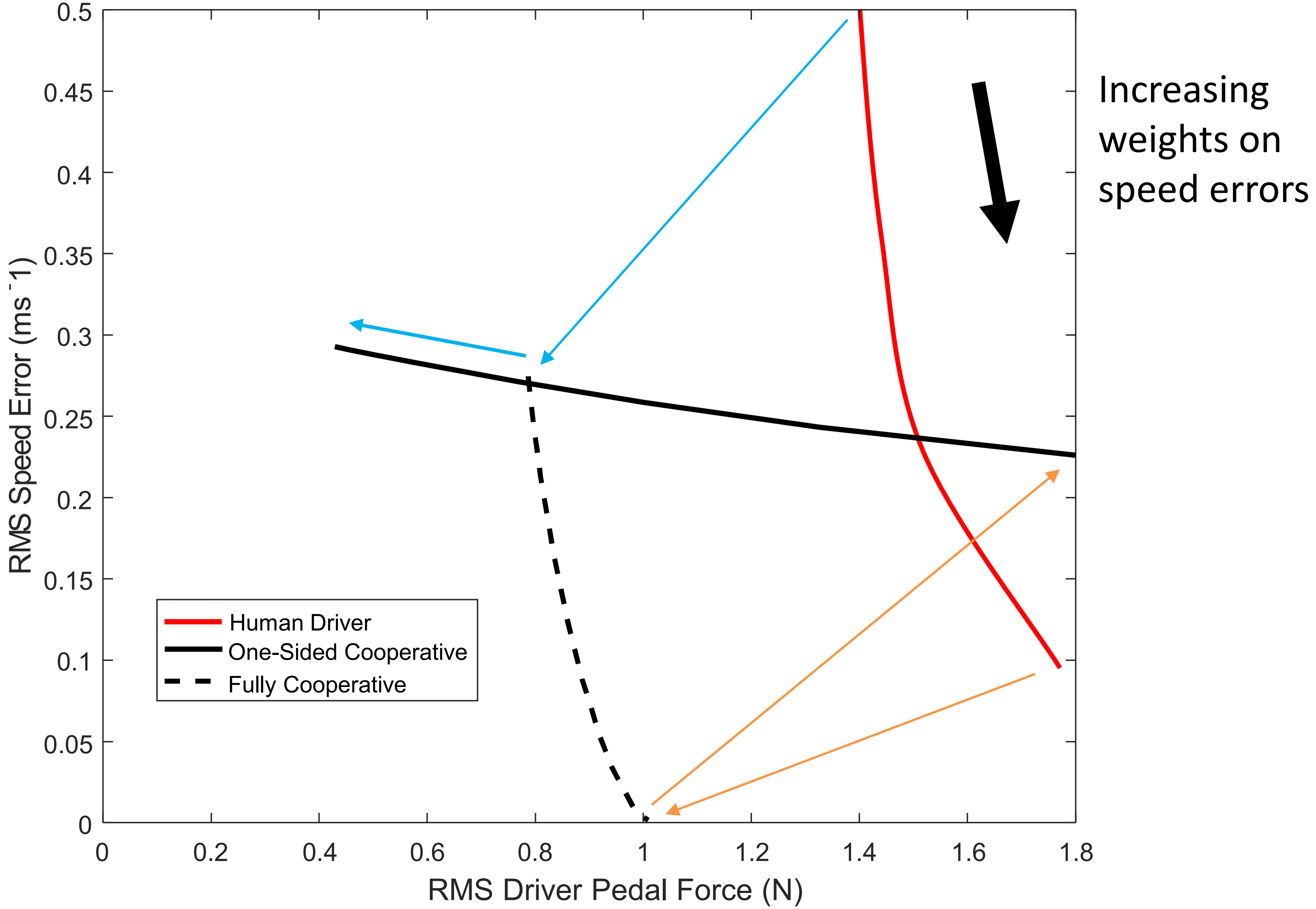

Speed focussed Driver:
$q_v = 80,$
$q_\phi = 1$

Eco Active Pedal:
$q_v = 30,$
$q_\phi = 1$

# Driving Styles

- An active pedal would need to work with a range of drivers and their individual driving styles
- By varying the driver's cost function weightings, different driving styles can be modelled
- Effects of different drivers on one active pedal examined

# Pedal Force and Speed Error



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# Conclusions

1. Mathematical game theory used to model interaction between driver and active pedal
2. Model Predictive Control theory used to implement two different control strategies: cooperative and one-sided cooperative
3. Parameter study has revealed a range of driving styles can be derived by varying parameters in the cost function

# Further Work

- Driving simulator experiments with professional drivers
- Analysis of on-road data
- More detailed engine and fuel consumption model from real data
- Design and assessment of force feedback strategies