The effects of “low-carbonisation” on vehicle dynamics

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LCVTP WS8

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Presentation

- Low Carbon Vehicles, the NAIGT roadmap and the LCVTP
- Options for low carbon vehicles
- Lightweighting
- Low drag
- Electric Propulsion
- Stability Issues of Regeneration

NAIGT Technology Road Map

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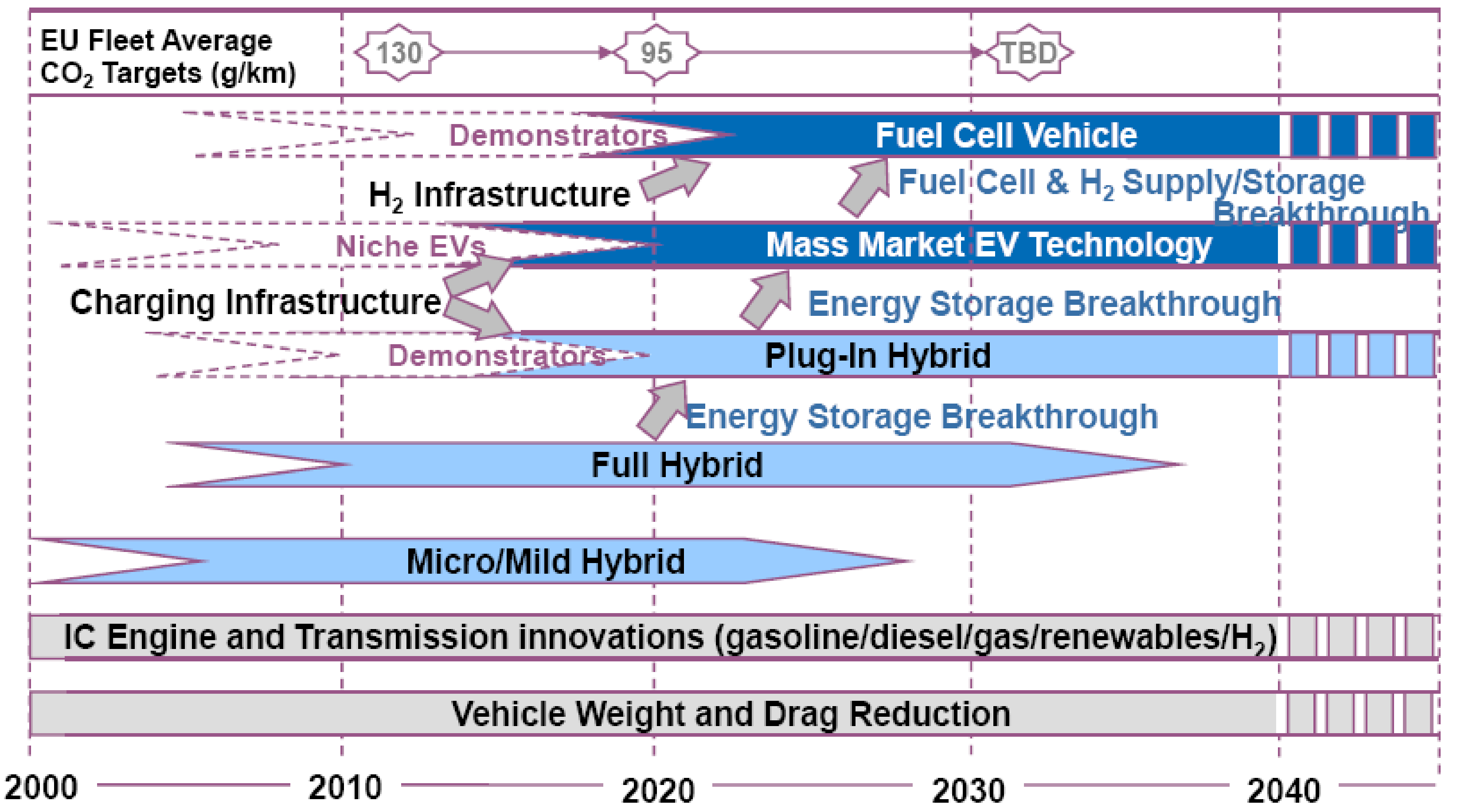


BIS:New automotive innovation and growth team

http://www.berr.gov.uk/policies/business-sectors/automotive/new-automotive-innovation-and-growth-team

Coventry University, Cranfield University, Jaguar, Land Rover, MIRA, Ricardo, Tata, WMG Innovative Solutions, Zytek Automotive

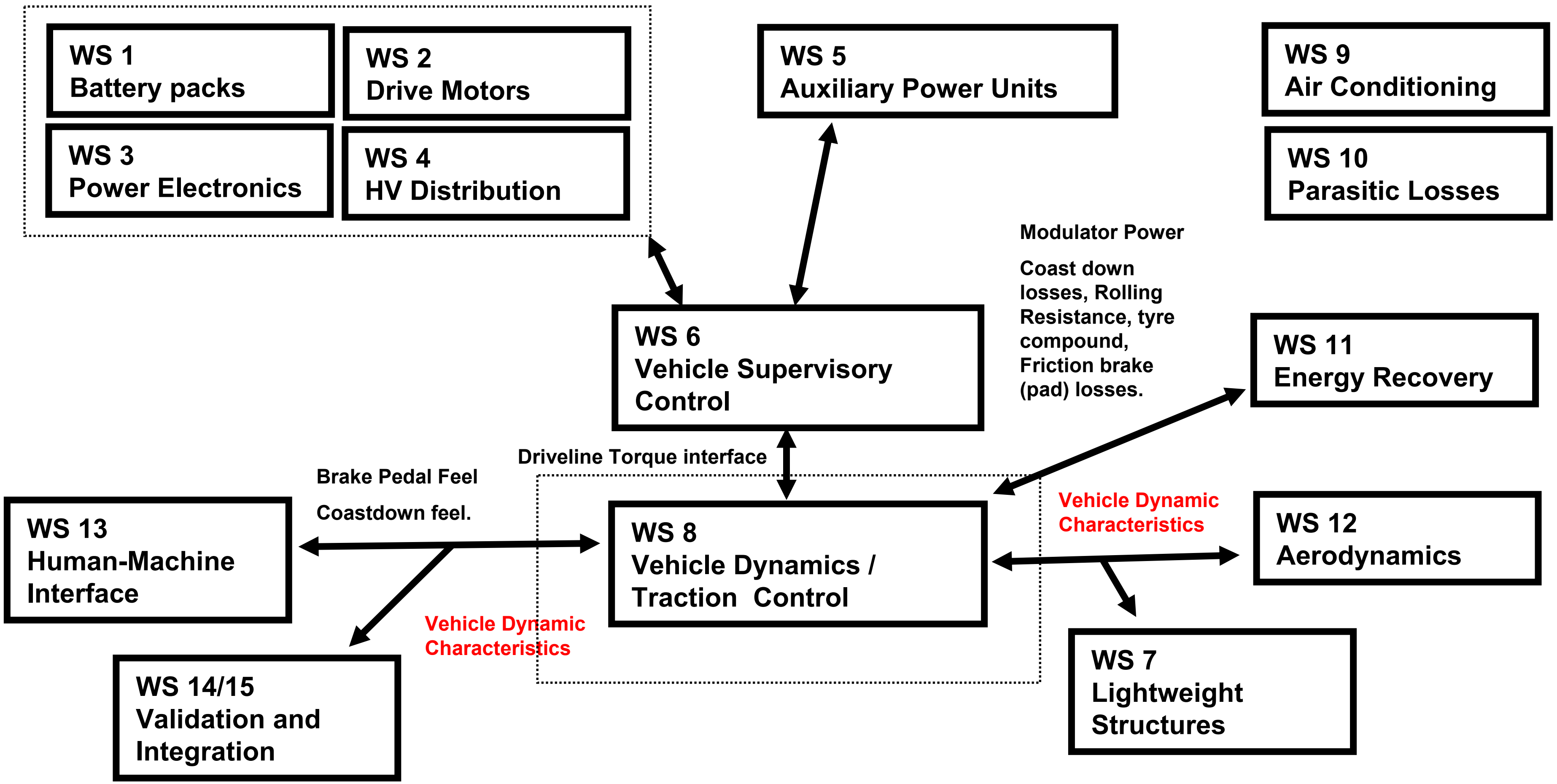
Low Carbon Vehicle Technology Project

- **A £29 million combined financial investment of AWM, ERDF & Industry**
- **Comprises 15 technical R&D workstreams.**

Low Carbon Vehicle Technology Project Announced

http://www2.warwick.ac.uk/fac/sci/wmg/mediacentre/wmgnews/lcvtplaunchannouncement

Low Carbon Vehicle Technology Project



Low Carbon Vehicle Dynamics

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- **What is unique about Low Carbon Vehicles from the dynamics point of view?**

Exotic Low carbon vehicles

- **Motorcycles**
- **Single passenger / track inclining vehicles**
  - **Nissan Land Glider**
  - **Lumeneo Smera**

Low carbon vehicles

- **Motorcycles**
- **Single passenger / track inclining vehicles.**
  - > **Nissan Land Glider**
  - > **Lumeneo Smera**
- **Small non-inclining vehicles**
  - > **Renault Twizi**

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  - > **Renault Twizi**
- **Conventional small cars**
  - > **Nissan Leaf**
- Conventional large cars
- :

Low carbon vehicles

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KPMG Technology Road Map

- *Given the desire for more economical engines, the vast majority of auto executives (around eight out of ten) believe that hybrids and electric cars will enjoy the biggest growth of any vehicle category over the next five years. However, total sales are still expected to lag well behind traditional internal combustion-powered cars over this period due to some significant challenges that have not yet been resolved, including: safety, reliability, comfort, image and, undoubtedly, cost.*

[http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Documents/Global-Auto-Executive-Survey-2011.pdf]

It is likely, therefore, that mass produced low carbon vehicles will have a similar configuration, size and operation characteristics to what we see on the roads today.

Low Carbon Vehicle Dynamics

- What is unique about *pragmatic* Low Carbon Vehicles from the dynamics point of view?
- Lightweighting
  - Barring a significant step change in materials, lightweighting will continue apace, using traditional engineering principles.
  - Flexible structures, and consequent active control techniques, if they offer considerable benefit to vehicle mass, may be a step change.
  - however, the switch to battery energy storage is likely to move overall mass of the vehicle in the other direction.

Low Carbon Vehicle Dynamics

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- **What is unique about Low Carbon Vehicles from the dynamics point of view?**
- **Lower Drag**
  - **Thinner and lower rolling resistance wheels and tyres**

    and the consequent detrimental effect on vehicle dynamics.
  - **More efficient aerodynamics**

    and the consequent detrimental effect on lift / weight distribution and vehicle dynamics.
  - **(also poorer forced convection cooling for the brakes)**

i.e. business as normal.

Low Carbon Vehicle Dynamics

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- What is unique about Low Carbon Vehicles from the dynamics point of view?

- **Electric propulsion**
- **Regeneration**

Electric Propulsion

> Higher reflected inertia of motor on drivetrain.

> Fewer gears, but no need of a clutch or fluid coupling.

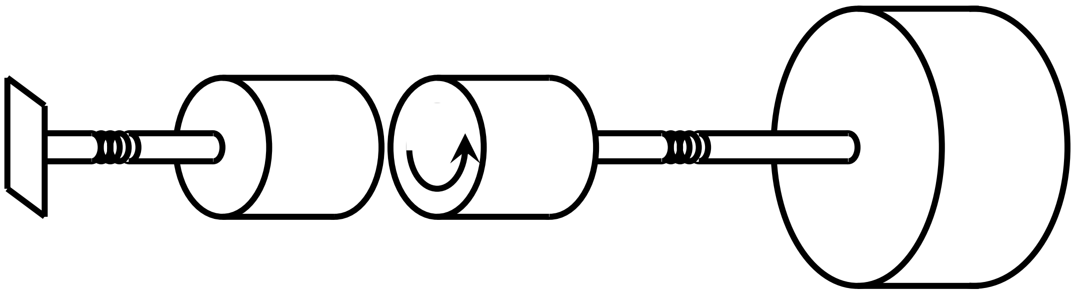
- Protection of the motor from transmission shocks?

> Faster response (perhaps?)

- Control system architecture of distributed (asynchronous) control.

Dynamics of wheel torque control

- **It is the torsional stiffness of drivetrains that limit the bandwidth of torque control.**



- **There may be new NVH requirements for electric engine mounts, Allowing higher stiffnesses from higher frequency isolation requirements.**
- **Higher temporal requirement for the electronic communication protocols, such as Flexray for synchronous distributed control algorithms.**

Electric Propulsion

> **Individual wheel motors, either in hub or inboard**

["Innovation by In-Wheel-Motor Drive Unit" Satoshi Murata, Toyota (Japan), AVEC 2010 Keynote]

- **Cost / package of inverters**
- **Unsprung mass**
- **Peak power / tractive force on split friction or all terrain surfaces.**

probably not.

The electric vehicle is therefore likely to have one prime mover, with torque conventionally vectored to two or four wheels.

(Electric) Regeneration

- **Individual wheel torque control is unlikely to be a problem, indeed it could significantly improve ABS/ESC. Potentially wheel position control could achieve very good slip management.**

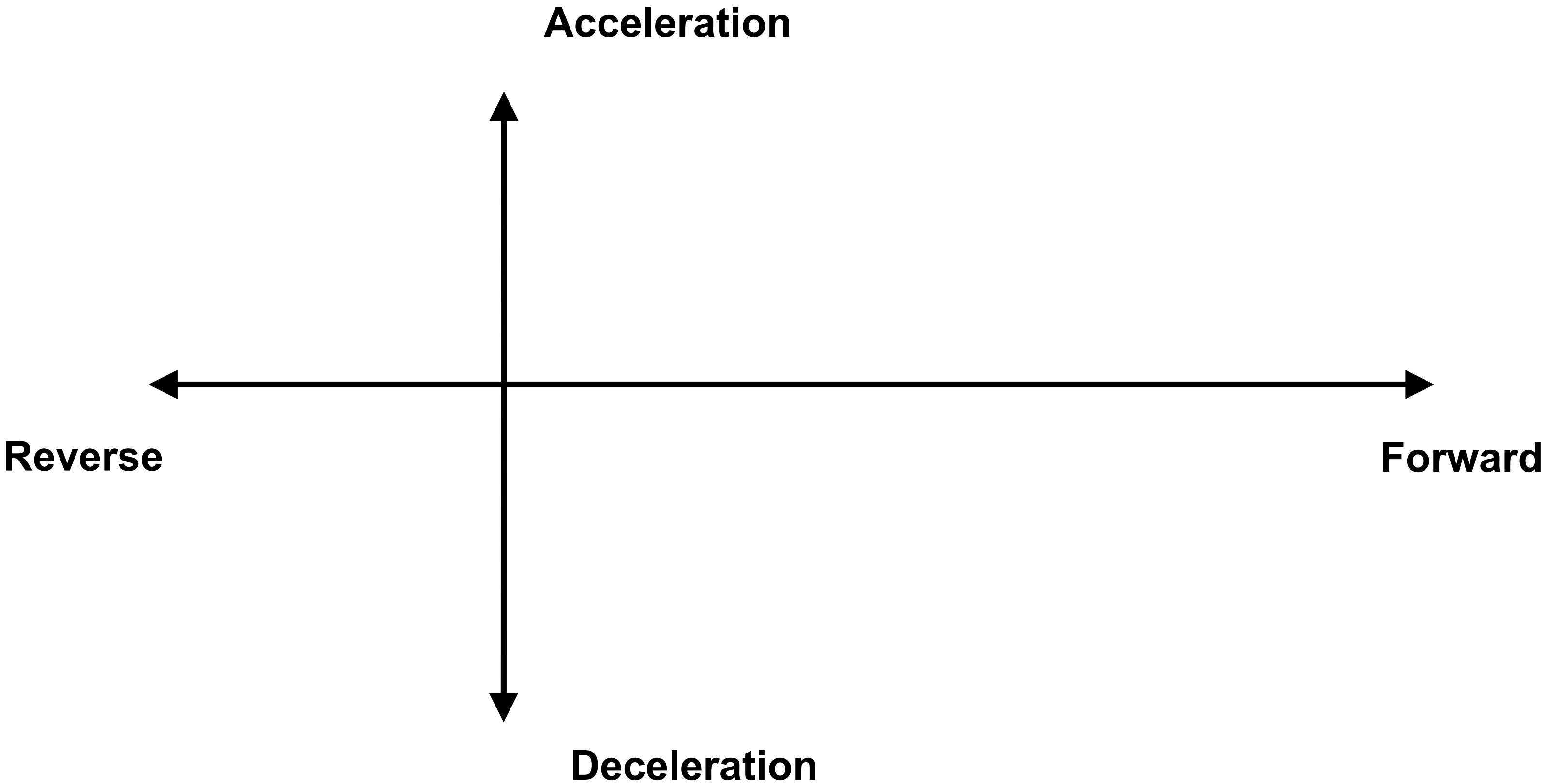
- **Worst case for stability will be for high level of regeneration (electric or otherwise) from a rear wheel drive system.**

- **Torque vectoring (left – right and/or front-back) using controlled mechanical differential(s) will pose similar problems to the acceleration quadrant.**

Stability issues of Regeneration

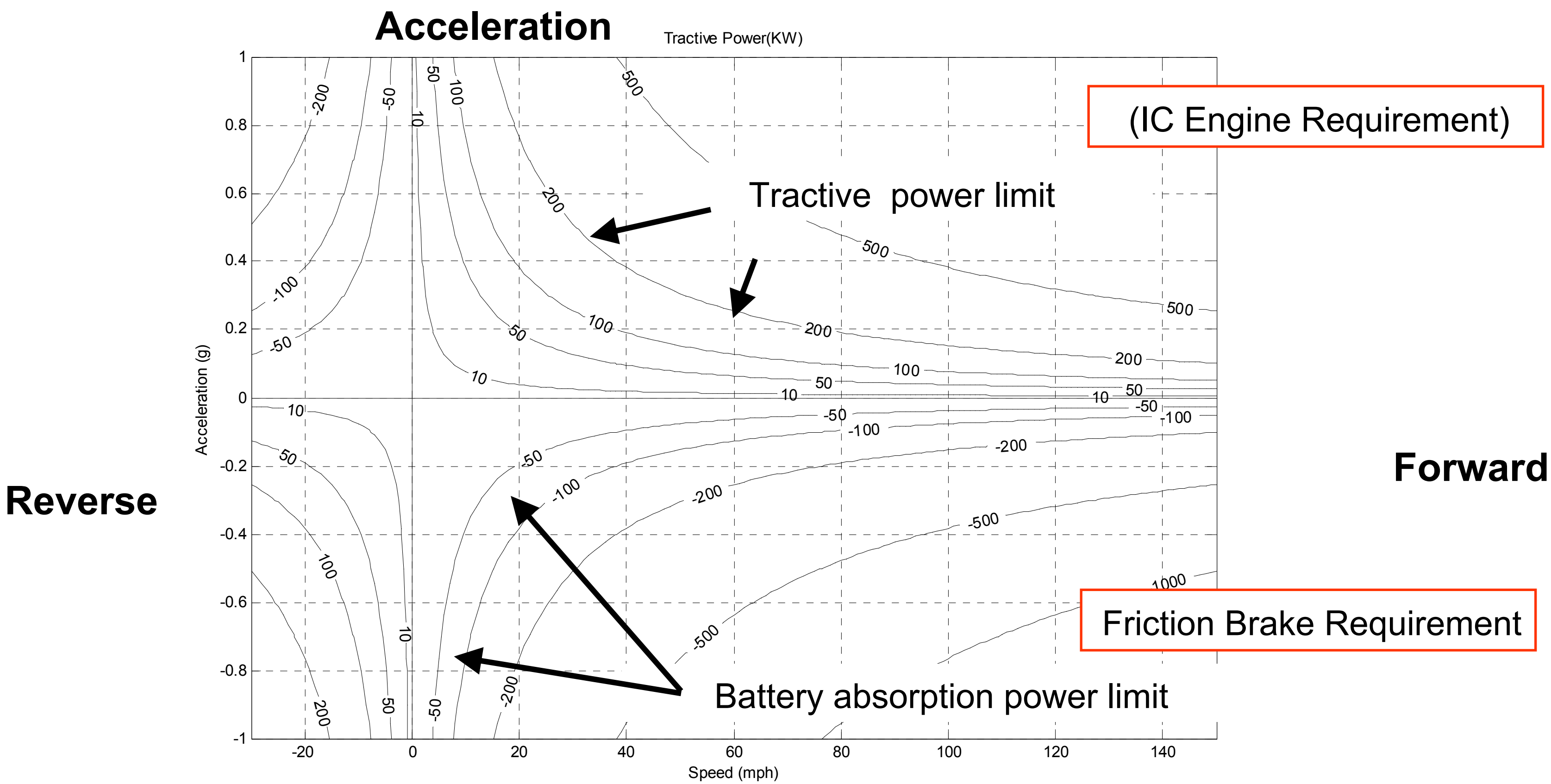
- **Braking systems using propulsion system technology**

- **Torque vectoring**



Stability Issues of Regeneration

Power available vs power useable



Notwithstanding weight transfer, or failure mode (lack of acceleration/deceleration)

If Battery Absorption < Traction Power, the regen. problem is less than the traction problem.

Regeneration Energy from Gradients

- Stokesley – Helmsley road over N.Y.Moors: (perfect, lossless car)

	Chain.	Height	Km at	Gradient	KWh	Time at	45	mph (	20.0	) m/s
	(m)	(m)				(s)		KW at	2500	Kg
Stokesley	0	**66**								
Broughton Br	1000	68	1.000	0.2%	0.014	50		1.0		
Great Broughton	2760	90	1.760	1.3%	0.150	88		6.1		
Clay Bank Summit	6790	**257**	4.030	4.1%	**1.138**	202		20.3		
Chop Gate	10600	167	3.810	-2.4%	-0.613	191		-11.6		
Laskill House	19900	125	9.300	-0.5%	-0.286	465		-2.2		
Newgate Bank Top	22000	**246**	2.100	5.8%	0.824	105		28.3		
Helmsley	29400	**59**	7.400	-2.5%	**-1.274**	370		-12		

Regeneration Energy from Gradients

- A6135 into Sheffield

	Chain.	Height	Km at	Gradient	KWh	Time at	20	mph (	8.9	) m/s
	(m)	(m)				(s)		KW at	2500	Kg
Westfield	0	106								
Highlane	1250	158	1.250	4.2%	**0.354**	141		9.1		
Spot Height	1880	128	0.630	-4.8%	-0.204	71		-10.4		
Spot Height	2870	165	0.990	3.7%	0.252	111		8.1		
Frecheville	3820	156	0.950	-0.9%	-0.061	107		-2.1		
Brook	4160	130	0.340	-7.6%	-0.177	38		-16.7		
A6102	5840	**195**	1.680	3.9%	0.443	189		8.4		
Town Centre	9000	**50**	3.160	-4.6%	**-0.988**	356		-10		

Stability Issues of Regeneration

- As the battery limitations are removed, regeneration at higher levels is possible.
- It may be desirable (pedal feel, NVH, longevity) to regenerate even if the energy cannot be re-used i.e. rheostatic braking.

Stability Issues of Regeneration

- On a rear wheel drive vehicle, an Electronic Limited Slip Differential (eLSD) can be used to stabilise sub-limit oversteer by providing yaw damping.
- An overspeed torque vectoring differential (TVD) can provide additional benefits during cornering and for understeer control.

Stability Issues of Regeneration

- On a front wheel drive vehicle, regenerative braking will induce understeer, the only counter to which is to apply friction braking to the rear and release braking torque from the front.

  As the inside wheel breaks traction, it will reverse in direction !

  This will relieve the torque on the outside wheel and stabilise the understeer.

- Locking the differential will allow more regen torque to be generated but will exacerbate the understeer

In conclusion

- Most low-carbonisation will continue the work as normal for vehicle dynamicists (tyre capability, mass distribution)
- Significant regeneration power is occasionally available, but at present is limited by
  - > Limited power of the regeneration machine
  - > Lack of reliability of the energy sink
  - > Torque vectoring.
  - > Lack of interest / rarity of situations in drivecycles.

In conclusion

- The biggest short term challenge for chassis dynamics will be the instability introduced by regeneration, particularly for rear wheel driven cars.
- In the short term, torque vectoring using classical active differentials could achieve greater regeneration, probably more than the current battery technology can cope with.
- As battery (or supercap, or flywheel energy storage) systems develop, stability control (ABS) of regenerative braking systems will become critical.