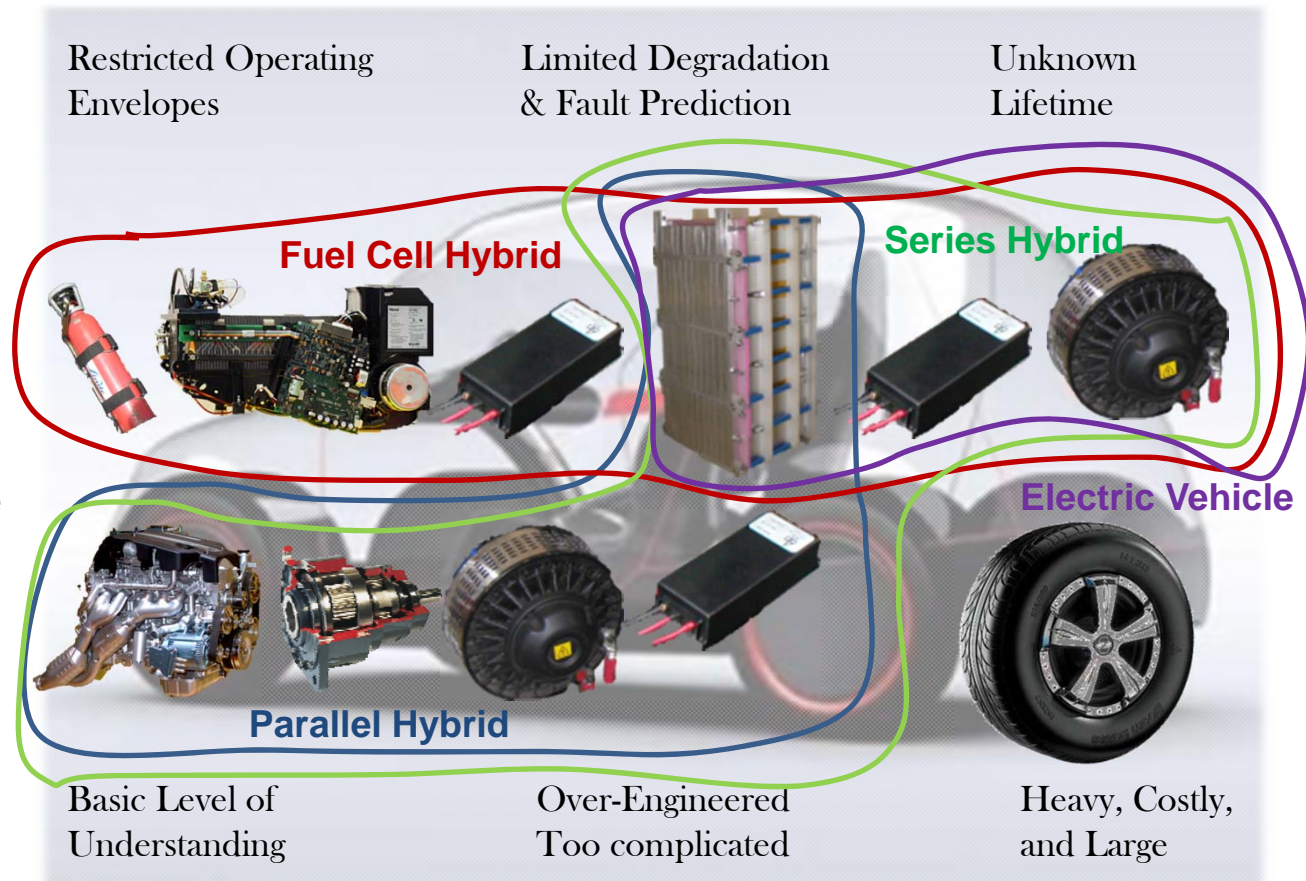


EPSRC Project “Developing  
FUTURE Vehicles  
(Fundamental Understanding  
of Technologies for Ultra  
Reduced Emission Vehicles)”

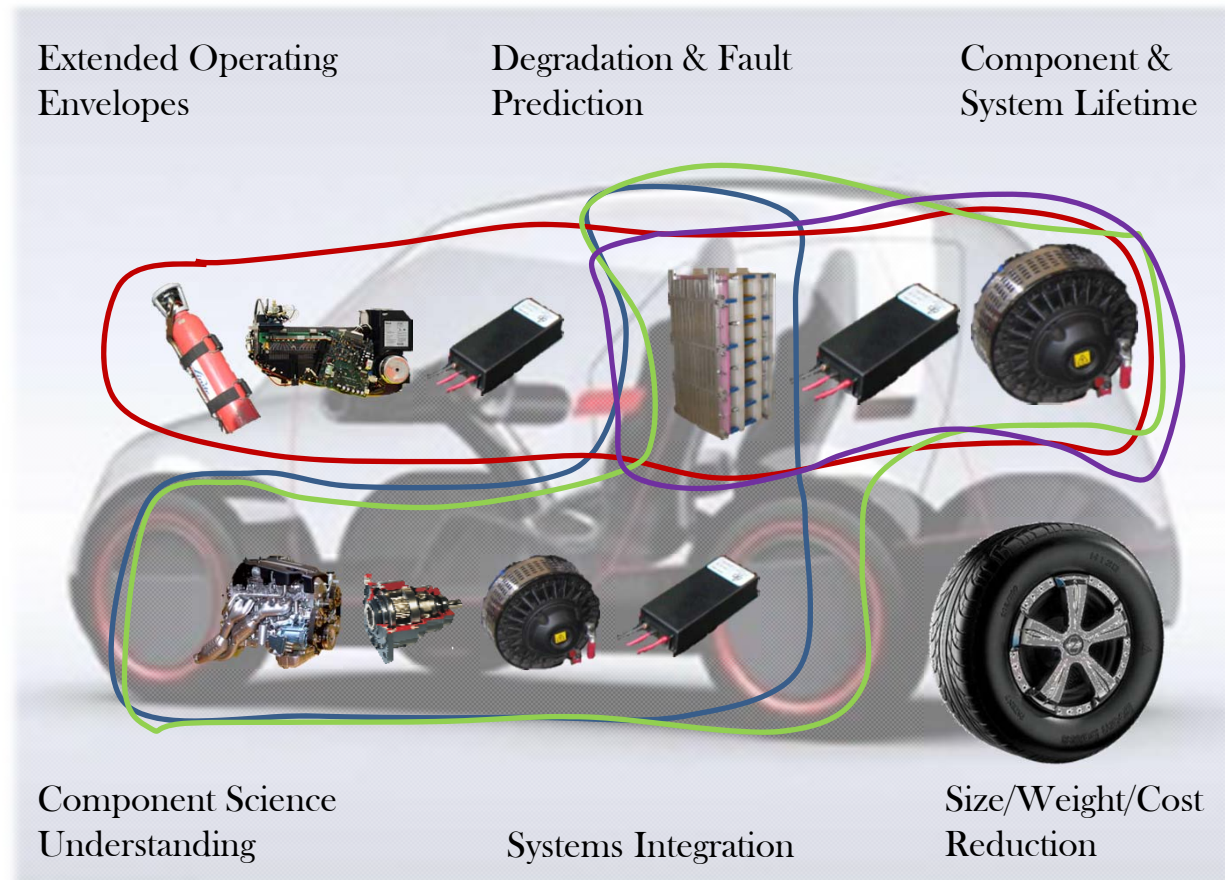
# Developing FUTURE Vehicles

- Some of the challenges
- Ultra Low Carbon Vehicles are coming
- Britain wants to be a leader.
- The knowledge is not all there
- Coherent programme of inter-related projects
- Significant step change in knowledge and understanding
- Held together by systems integration



# Impacts & Outputs

- **Lexicon of information**
  - To include...
- **Library models**
  - Control & reduced order
  - Detailed high fidelity
- **Unified open source approach/methodology**
  - Developing models
  - Parameterisation (exp)
- **Better understanding components**
  - Under extremes
  - Fault conditions
  - Lifetime/Degradation
- **Emergent behaviour**
  - Interactions
  - Systems optimisation



Unique to consortium, added value of interdisciplinary approach.  
High impact, will aim to be a reference for systems engineers .

**Cross-cutting Theme 1:** Thermal analysis, failure and degradation diagnosis and prognosis

**Work Package 1:** chemical energy storage systems plant modelling

Fuel cells, batteries and supercapacitors

Power electronics

**Work Package 2:** electrical energy converter systems plant modelling

Electrical machines

**Work Package 3:** reduced order modelling and controls

Unified modelling framework

Optimisation and control design

**Cross-cutting Theme 2:** Reduced order models

**Cross-cutting Theme 3:** Limits of performance by application of advanced control

Energy flow

Information flow

# Objectives (1)

- Obtain an in-depth and better understanding of the Science behind:
  - Batteries
  - Supercapacitors
  - Fuel Cells
  - Power Electronics
  - Electric machines and electric machine drives

# Objectives (2)

- Provide a systematic and unified approach to:
  - Failure modes
  - Prognostic indicators
  - Especially at the limits of performance
- Produce a “codified lexicon” of component models, including thermal and aging models

# Objectives (3)

- Generate reduced order models of the components in Objectives (1)
- Demonstrate advanced control methodologies
- Diagnostics and Prognostics
- Failure modes and lifetime prediction
- HIL demonstrations

# What is outside the scope?

- Vehicles – we will not be producing whole vehicles
- IC engines are specifically excluded – there are many existing projects in this area
- Specific configurations – this project is in TRLs 1,2,3



# Project Partners

## Academia

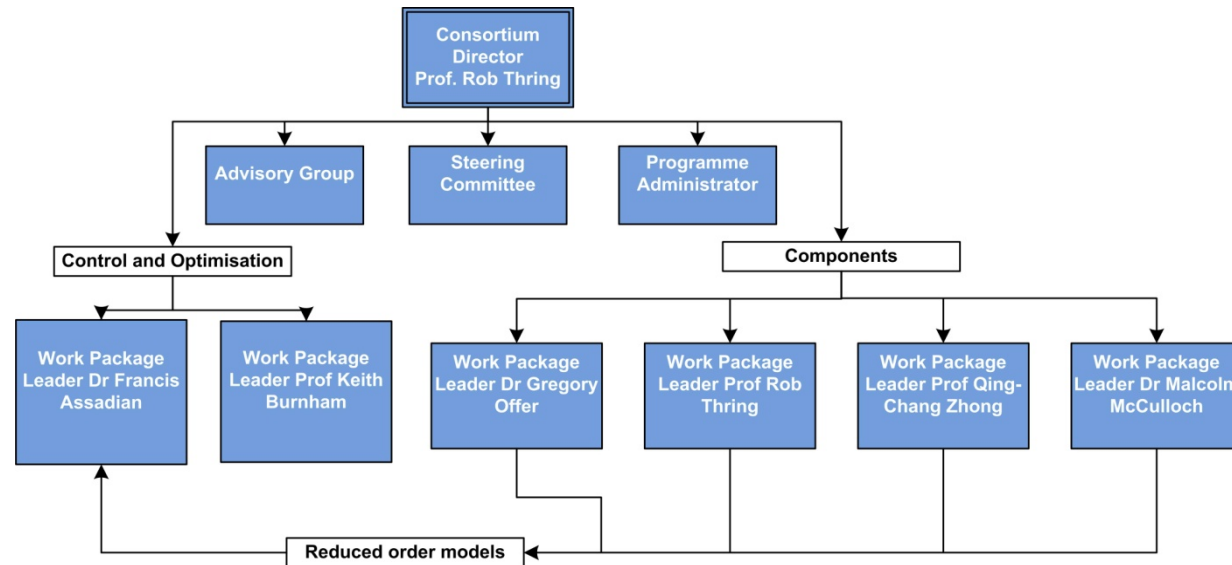
- Loughborough University (Lead)
- Imperial College, London
- University of Oxford
- Cranfield University
- Coventry University
- Sheffield University

## Industry

- AVL Powertrain UK Ltd
- Cenex
- Dennis Eagle Ltd
- Intelligent Energy Ltd
- MIRA Ltd
- SAIC Motor UK Ltd
- TUV Nord Mobilitat
- Jaguar Land Rover
- Lotus
- Axeon
  - Joining...
- Vector Fields, Cobham Tech Serv
- Hirst Magnetic Instruments
- Nidec SR Drives

# Project Funded, thanks to EPSRC

- £3.1M
- Start date; 1<sup>st</sup> December, 2011
- Duration: 4 years



Management Strategy

# Outputs so far...

Journals				
No.	Title	Authors	Journal	Publication Date (done or planned)
1	Module design and fault diagnosis in electric vehicle batteries	Offer, G. J., Yufit, V., Howey, D. A., Wu, B., Brandon, N. P.	Journal of Power Sources, Volume 206, May 2012, pp.383-392. DOI:206:383-392	May-12
2	An Optimization Framework for Comparative Analysis of Multiple Vehicle Powertrains.	Mohan, G., Assadian, F., Longo, S	Energies 2013, 6, p5507-5537. DOI:10.3390/en6105507	Oct-13
3	A Novel Method for the Parameterization of a Li-Ion Cell Model for EV/HEV Control Applications	Antaloae, C. AVL Powertrain UK Ltd., Basildon, UK, Marco, J., Assadian, F.	Vehicular Technology, IEEE Transactions on (Volume:61, Issue:9) Nov 2013, pp. 3881-3982	Nov-13
4	Coupled thermal–electrochemical modelling of uneven heat generation in lithium-ion battery packs	Wu, B., Yufit, V., Marinescu, M., Offer, G. J., Martinez-Botas, R., F., Brandon, N., P.	Journal of Power Sources, Volume 243, December 2013, pp. 544-554. ISSN:0378-7753	Dec-13
5	The effect of thermal gradients on the performance of lithium-ion batteries	Troxler, Y., Wu, B., Marinescu, M., Yufit, V., Patel, Y., Marquis, A. J., Brandon, N.P., Offer G. J.	Journal of Power Sources, Volume 247, February 2014 (June 2013) , pp.1018-1025. ISSN:0378-7753	Feb-14
6	Mechatronics in Sustainable Mobility: Two Electric Vehicle Applications	Longo, S., Auger, DJ & Assadian, F	Journal of Sustainable Mobility 2013 (under revision)	
7	Degradation and Failure of Electric Machines in Electric and Hybrid Vehicles	Darren Kavanagh		Under preparation
8	Spatial Multi-stress Degradation Modelling of Thin-Film Insulation in Electric Machines	Darren Kavanagh		Under preparation

# Outputs so far...

Conferences			
No.	Title	Authors	Publication Date (done or planned)
1	?	Gregory Offer and Dave Howey	World Electric Vehicle Summit 2012, 12-14 June, Copenhagen Denmark
2	Influence of Cost Function on EV Powertrain Sizing	Mohan, G., Assadian, F. and Marco, J	Powertrain Modelling and Control 2012, September 4, Bradford UK
3	Reduction of DC-bus voltage ripples and capacitors for single-phase PWM-controlled rectifiers	Zhong, Q.-C., Ming, W.-L., Cao, X. and Krstic, M.	IECON 2012 - 38th Annual Conf. IEEE Industrial Electronics Society, Oct 25-28, pp. 708-713.
4	The effect of temperature gradients on the performance of Li-ion batteries	Marinescu, M., Troxler, Y., Wu, B., Yufit, V., Patel, Y., Marquis, A. J., Brandon, N. P., Offer, G. J.	10th Symposium for Fuel Cell and Battery Modelling and Experimental Validation 2013 (Modval 2013), March 19-20, Bad Boll/Stuttgart, Germany
5	Improving the power quality of traction power systems with a single-feeding wire	Zhong, Q.-C., Ming, W.-L., and Krstic, M	IEEE Green Technologies Conference, 2013 April 4-5, pp. 233-238
6	Thermal and Water Balance in an Evaporatively Cooled PEM Fuel Cell Vehicle	Fly, A. and Thring, R.H.	IMEchE conference on Vehicle Thermal Management Systems 2013 (VTMS11), May 15-16, Coventry Technocentre, UK, pp.267 - 277
7	Electric Vehicles	Gregory Offer	Renault/Nissan Alliance Conference 2013, June 25, Brussels
8	The effect of temperature gradients on the performance of Li-ion batteries	Marinescu, M., Troxler, Y., Wu, B., Yufit, V., Patel, Y., Marquis, A. J., Brandon, N. P., Offer, G. J.	6th International Conference on Polymer Batteries and Fuel Cells 2013 (PBFC 2013), June 3-7, Ulm, Germany
9	Future of transport in 20 years time	Gregory Offer	Tech Foresight Conference 2013, July 5, Imperial College London
10	An Applied Laboratory Characterisation Approach for Electric Machine Insulation	Kavanagh, K., Howey, D., McCulloch, M	9th IEEE International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives 2013 (SDEMPED13) Valencia, Spain, August 27-30. pp 391-395
11	The Impact of Battery Ageing on an Electric Vehicle Powertrain Optimisation	Auger DJ, Groff MF, Mohan G, Longo S & Assadian F	The 8th Conference on Sustainable Development of Energy, Water and Environment Systems 2013 (SDEWES 2013), September 22-27 Dubrovnik, Croatia
12	Computational Aspects of Estimation Algorithms for Battery-Management Systems	Papazoglou A, Longo S, Auger DJ & Assadian F	The 8th Conference on Sustainable Development of Energy, Water and Environment Systems 2013 (SDEWES 2013), September 22-27, Dubrovnik, Croatia
13	Investigation of Model Order Reduction techniques: A Supercapacitor case study	Aizad, T., Sumislawska, M., Maganga, O., Agbaje, O., Phillip, N., Burnham, K. J	International Conference on Systems Science 2013, September 10-12, Wroclaw, Poland
14	Comparative analysis of forward-facing models vs backward-facing models in powertrain component sizing	Mohan, G., Assadian, F. and Longo, S	IET 4th Hybrid and Electric Vehicles Conference 2013 (HEVC13), November 6-7, London
15	Reduction of high fidelity lithium-ion battery model via data-driven system identification	Sumislawska, M., Phillip, N., Marinescu, M. M., Burnham, K. J	IET 4th Hybrid and Electric Vehicles Conference 2013 (HEVC13), November 6-7, London
16	Estimation of temperature dependent equivalent circuit parameters for traction-based electric machines"	Agbaje, O., Kavanagh, D. F., Sumislawska, M., Howey, D. A., McCulloch, M. D., Burnham, K. J	IET 4th Hybrid and Electric Vehicles Conference 2013 (HEVC13), November 6-7, London
17	The effect of thermal gradients on the performance of battery packs in automotive applications	M M Marinescu, M., Wu, B., Yufit, V., Offer, G. J., Von Sbrink, M. T	IET 4th Hybrid and Electric Vehicles Conference 2013 (HEVC13), November 6-7, London

# Outputs so far...

Workshops/Presentations				
No.	Title	Authors	Workshops/Presentations	Publication Date (done or planned)
1	FUTURE Vehicles Project	Thring, R	Atlanta Workshop, March 2012	Mar-12
2	?	Malcolm McCulloch and Dave Howey	Resource 2012, 12-13 July, Oxford University	Jul-12
3	FUTURE Vehicles Project	Thring, R.	Cenex LCV 2012, September 5-6, Bedfordshire	Sep-12
4	FUTURE Vehicles Project	Thring, R., Offer, G. J., Marinescu, M., Kavanagh, D., Assadian, F., Phillip, N.	FUTURE & VESI Dissemination Seminar 2013, January 15, Warwick	Jan-13
5	FUTURE Vehicles Project	Burnham, K., Phillip, N	FUTURE Vehicles Reduced Order Modelling Workshop 2013, April 22, Coventry University	Apr-13
6	FUTURE Vehicles Project	Thring, R	Low Carbon Vehicle Partnership Innovation Working Group (IWG-A-13-10), October 10, 2013, Loughborough University	Oct-13
7	FUTURE Vehicles Project	Assadian, F., Longo, S., Auger, D	FUTURE Vehicles Controls Workshop 2013, November 28, Cranfield University	Nov-13

# Outputs so far...

- All outputs are posted on the FUTURE Vehicles project website, URL:  
<http://www.futurevehicles.ac.uk/>

# An Aspiration

- We want the results to feed into future industry work in TRLs 4,5,6.
  - Dissemination events (January, 2013, January, 2014)
  - Should lead to benefits for UK PLC

Acknowledge EPSRC