TIGERS

(Turbo-generator Integrated Gas Energy Recovery System)

PROJECT OVERVIEW

1st June 2005

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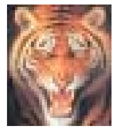
Foresight Vehicle

Agenda

- Project Management
- Visteon UK Ltd:
  IPR, recoverable energy, test cycles, OEM system requirements, vehicle package.
- University of Sheffield (UoS): (material provided by Melanie Michon)
  Energy recovery modelling, vehicle electrical system architectures, energy storage media.
- SR Drives (SRD) Ltd: (material provided by Paul Sykes)
  SR Machine & Power electronics modelling and design.



Objectives – DTI Offer Letter

" …to develop enabling technologies and integration techniques for an exhaust energy recovery system and to demonstrate its commercial viability…"

DTI TIGERS offer letter December 2003

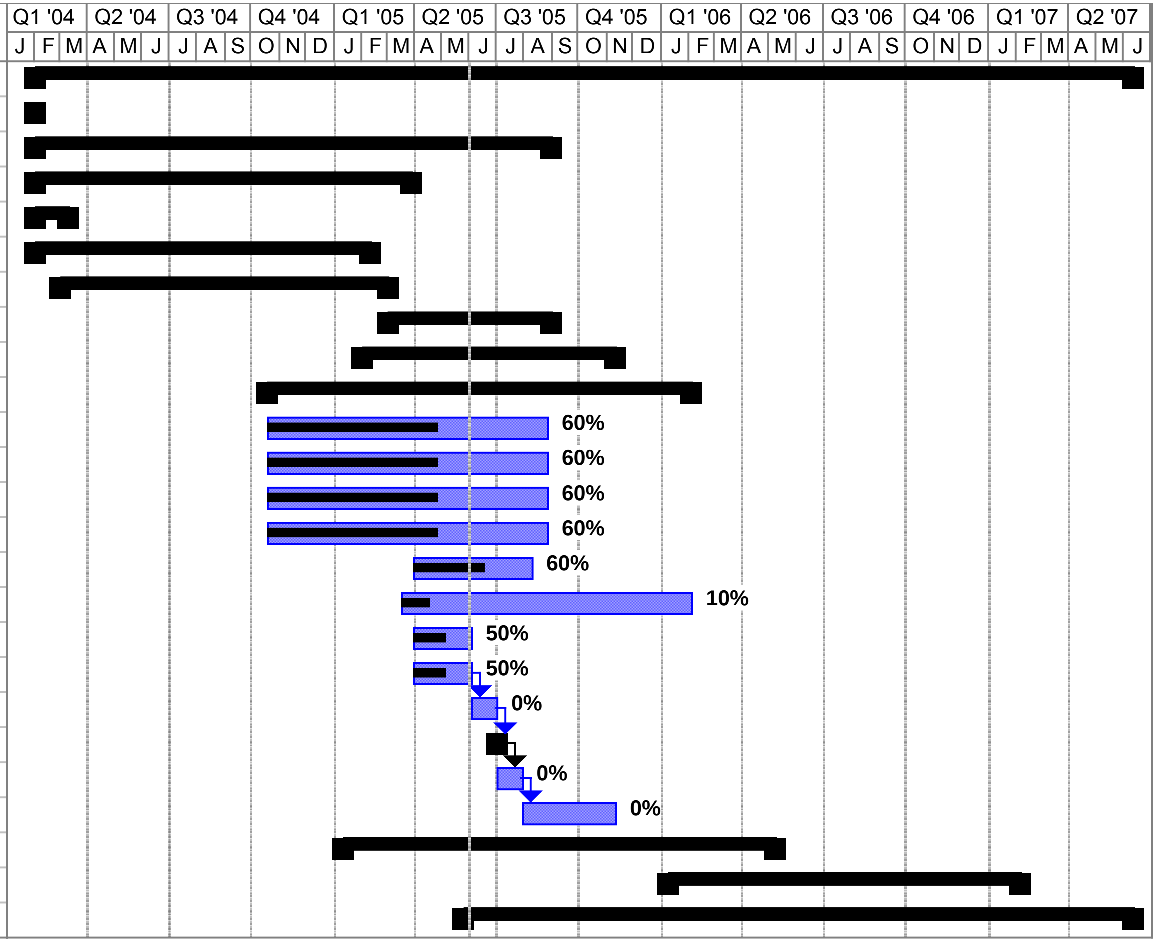
PROJECT COST BREAKDOWN

Organisation	Duration (Years)	Contribution (£k)	Grant (£k)	Total (£k)
Visteon	3	225	135	360
SR DRIVES	3	225	135	360
	3		180	180

Totals	**450**	**900**

Project Timing Plan

ID	Task Name
1	**Total Project**
2	Project Kick Off
3	**Phase 1 - Conceptual Study**
4	**State of the art investigation**
11	**Evaluate Available exhaust gas energy**
16	**Methods of energy capture & architechture**
25	**Determine suitablity of candidate technologies**
30	**System concept design**
42	**Electrical system optimisation & design**
48	**Detailed mechanical design**
49	Electromagnetic design
50	Detailed performance analysis (iron & aerodynamic losses)
51	Structual analysis (stress/rotor/dynamics)
52	Detailed thermal analysis / cooling system design
53	High temperature insulation evaluation
54	BOM
55	Turbine & volute design
56	Machine design
57	Waste gate design
58	Design freeze
59	Detailed drawings
60	Procure parts
61	**Converter & control design**
73	**Demonstration system**
86	**Documentation**



Foresight Vehicle

Visteon

SR DRIVES

Visteon UK Ltd

- Patent/Literature Search
- Identify Target Vehicle/Market Segment
- Identify Drive Cycles for Modelling
- Determine Energy Recoverable
- Develop Turbine Design
- Provide Vehicle Electrical Load Data

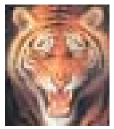
Patent Search

- Two searches have identified 350(+) patents covering exhaust energy recovery and automotive uses of SR machines. However:

  - Many are time expired and there is so much prior art we will be able to develop and market TIGERS.

  - There are no references to the use of SR machines for exhaust energy recovery devices.

  - There are one (possibly two) applications/features that we may still be able to Patent for TIGERS.



Target Vehicle/Market Segment

- Diesel PT already have higher efficiency than Gas. Diesel base engine costs now much higher than gasoline - OEM's finding it difficult to justify additional new technologies. Market segmentation appears to be stabilising around 50%.

- Gasoline PT closing efficiency 'gap' with addition of advanced technologies. Boosted/downsized gas ~ 8-10% market by 2008. Remaining NA gasoline segment is opportunity for new technology.

- C/D class segment needs help to meet 140g/km. This class is the last 'high volume' segment. Customers will pay for new technology. High 'out of urban' usage.

→ C/D segment NA Gasoline Target Platform

Drive Cycles

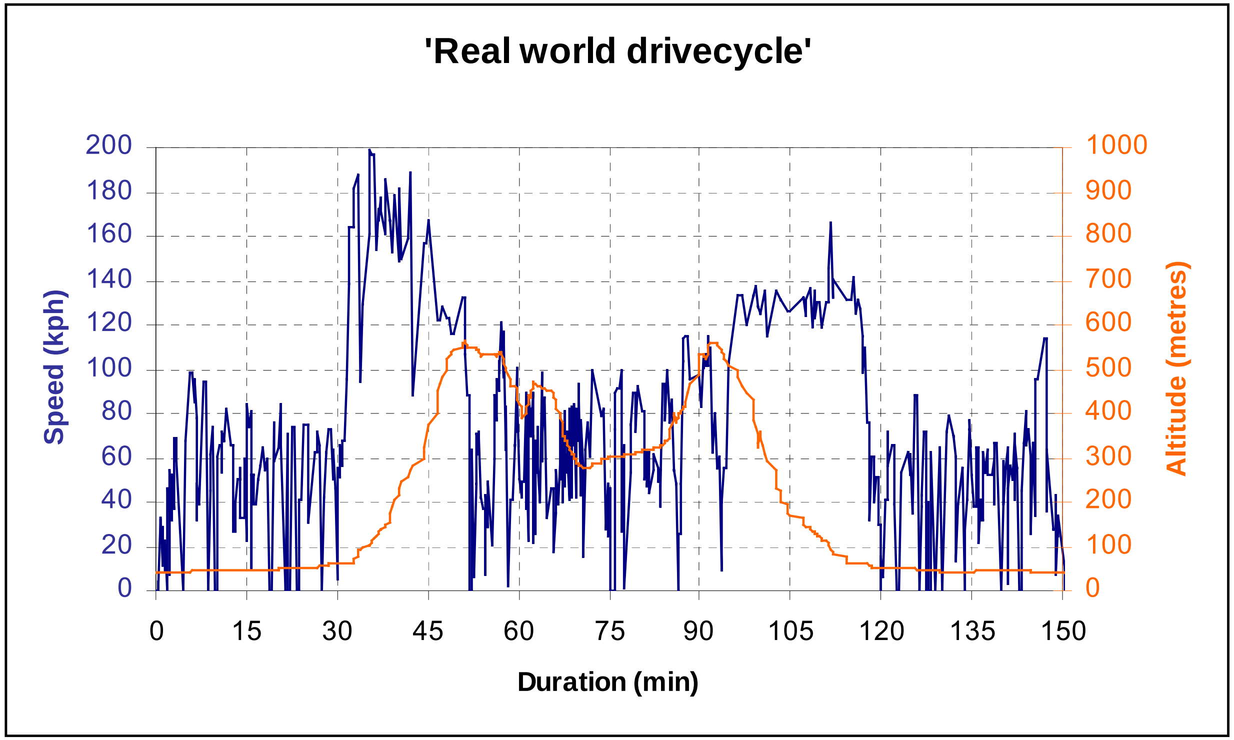
- Legislated - committed to CO_2 reduction but may not reflect 'Real world' usage.
- Recommend 'Real World' cycle such as Auto Zeitung:

2.5 Hours duration

0 – 200km/h

Significant gradients

Higher engine loading



Energy Recoverable

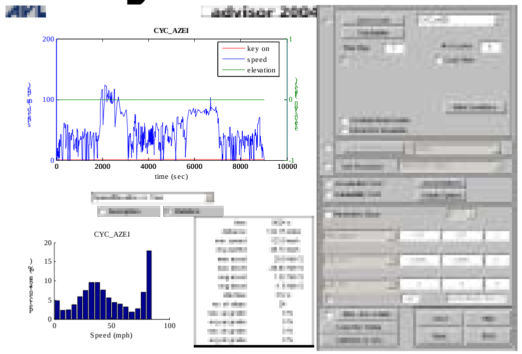
- Commercially available ICE simulation package modified to include ‘power turbine’.
- AZ cycle simplified to top 10 residency points (=80/ 90% of cycle).
- Simulations run at 3 locations in exhaust system and range of turbine speeds, loads and exhaust backpressure.
- Indicates that 50w – 13 kW may be extracted by turbine
- Follow up work to automate data handling and fully populate AZ cycle map (~900 points!)

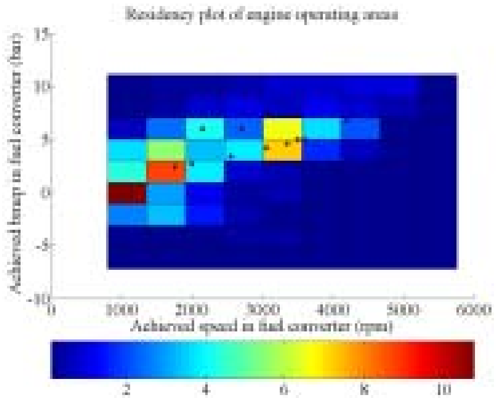
The University of Sheffield

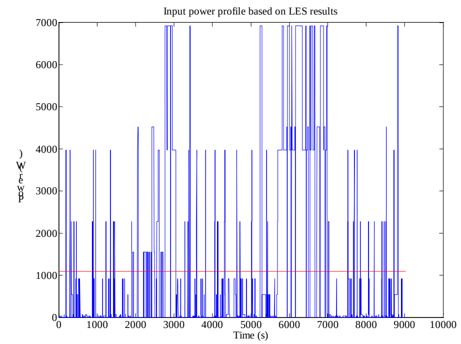
- Electrical System Energy Recovery Modelling
- Electrical System Topologies
- Energy storage Media

TIGERS Turbine Power Study

- ❑ **Driving Cycle**
  - Auto Zeitung
- ❑ **Vehicle Simulation**
  - ➢Advisor
- ❑ **Residency Data**
  - ➢map points / curve fitting
- ❑ **Engine/Turbine Simulation**
  - ➢Visteon: Lotus Engine Simulator
- ❑ **Electrical Input Power**

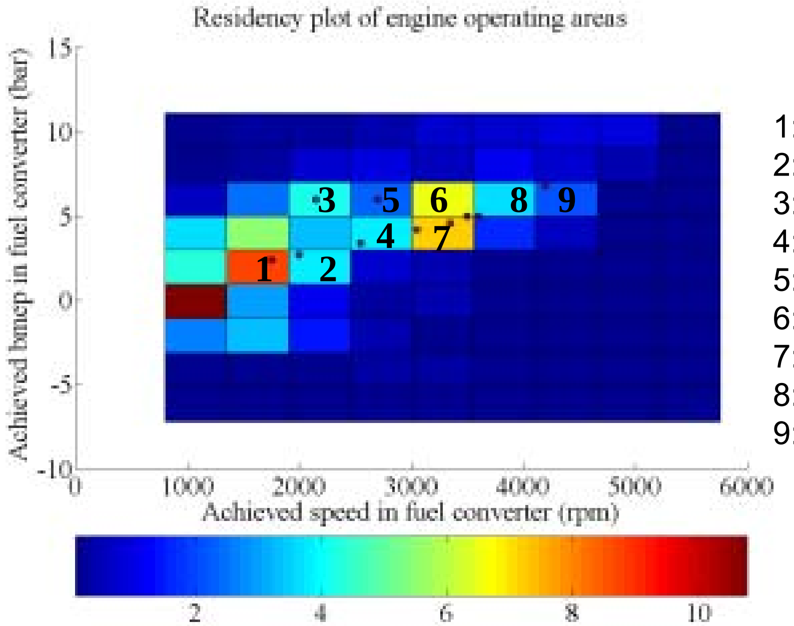




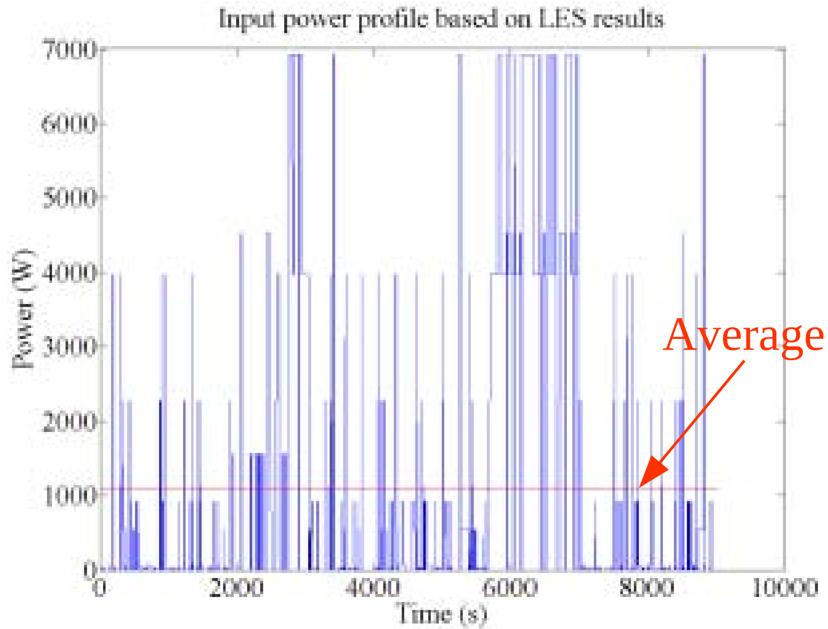


Foresight Vehicle Visteon SR DRIVES

Energy Storage Sizing Study for TIGERS



1: 30.4W
2: 67.5W
3: 920W
4: 538.2W
5: 2271W
6: 3968W
7: 6919W
8: 4520W
9: 1558W



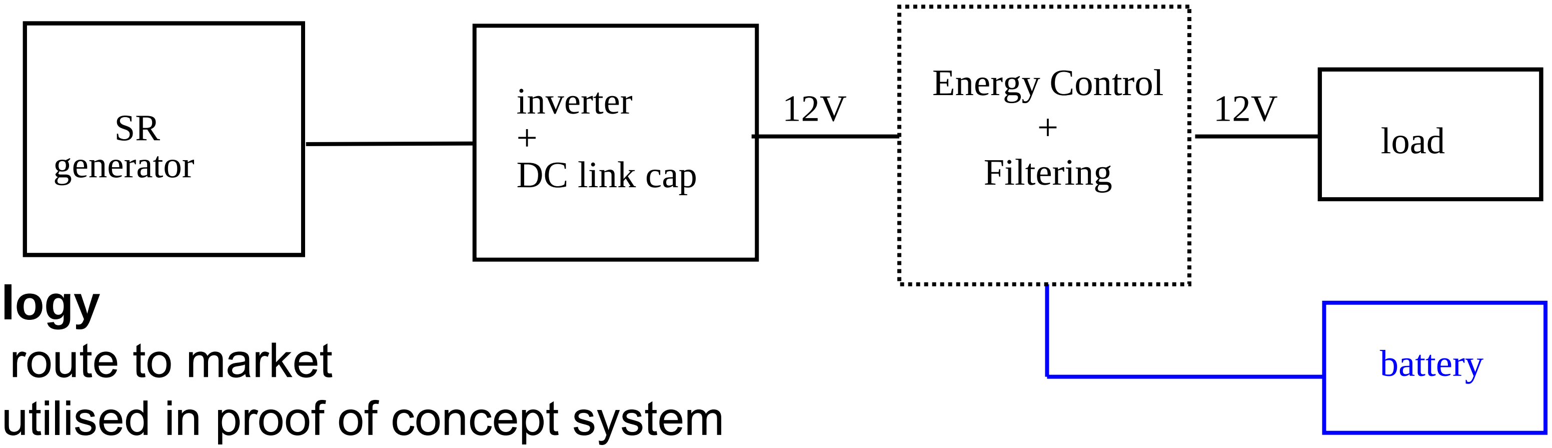
C/D class car:

- Idling load requirement: 62A constant
- Average load requirement over CLCC driving cycle: 70A constant

Conclusions:

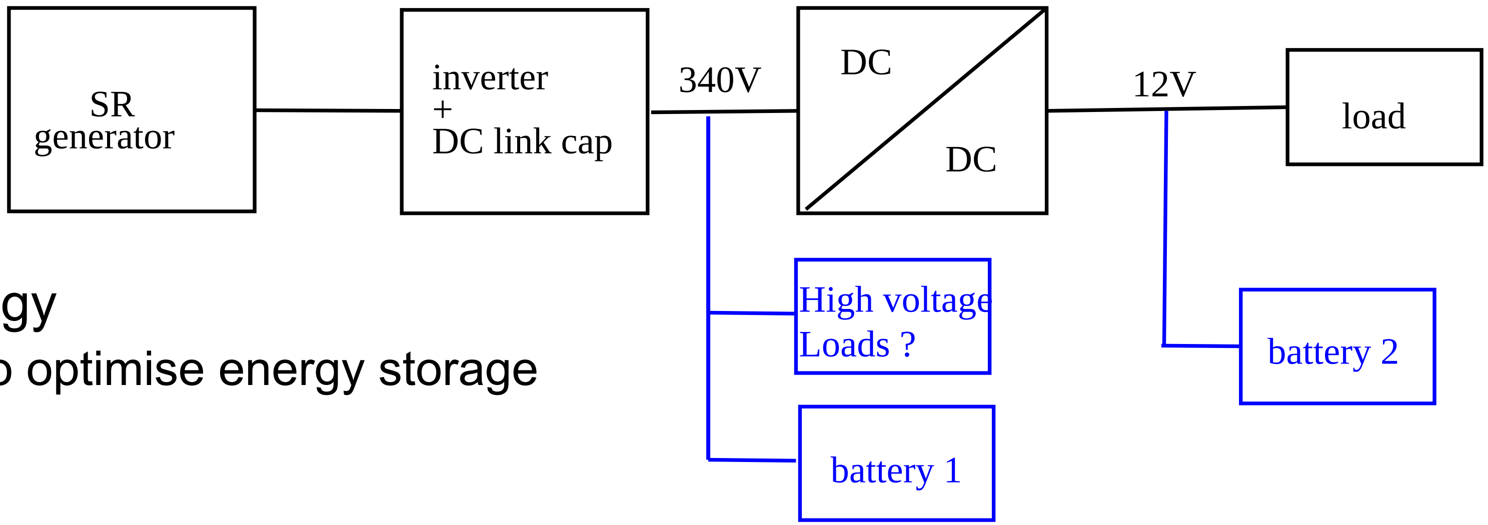
- C_{bat}: based on first simulation: ≥150Ah to delete alternator
- Driving cycle dependant: requirement to study other cycles e.g. NEDC no motorway cruising, etc.

Energy Storage Topology Study for TIGERS



12V topology

- fastest route to market
- will be utilised in proof of concept system



340V topology

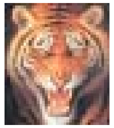
- potential to optimise energy storage

SRD UK Ltd

- SR machine design assumptions
- High frequency loss investigations
- Thermal design
- Manufacturing processes

SR Machine Design Assumptions

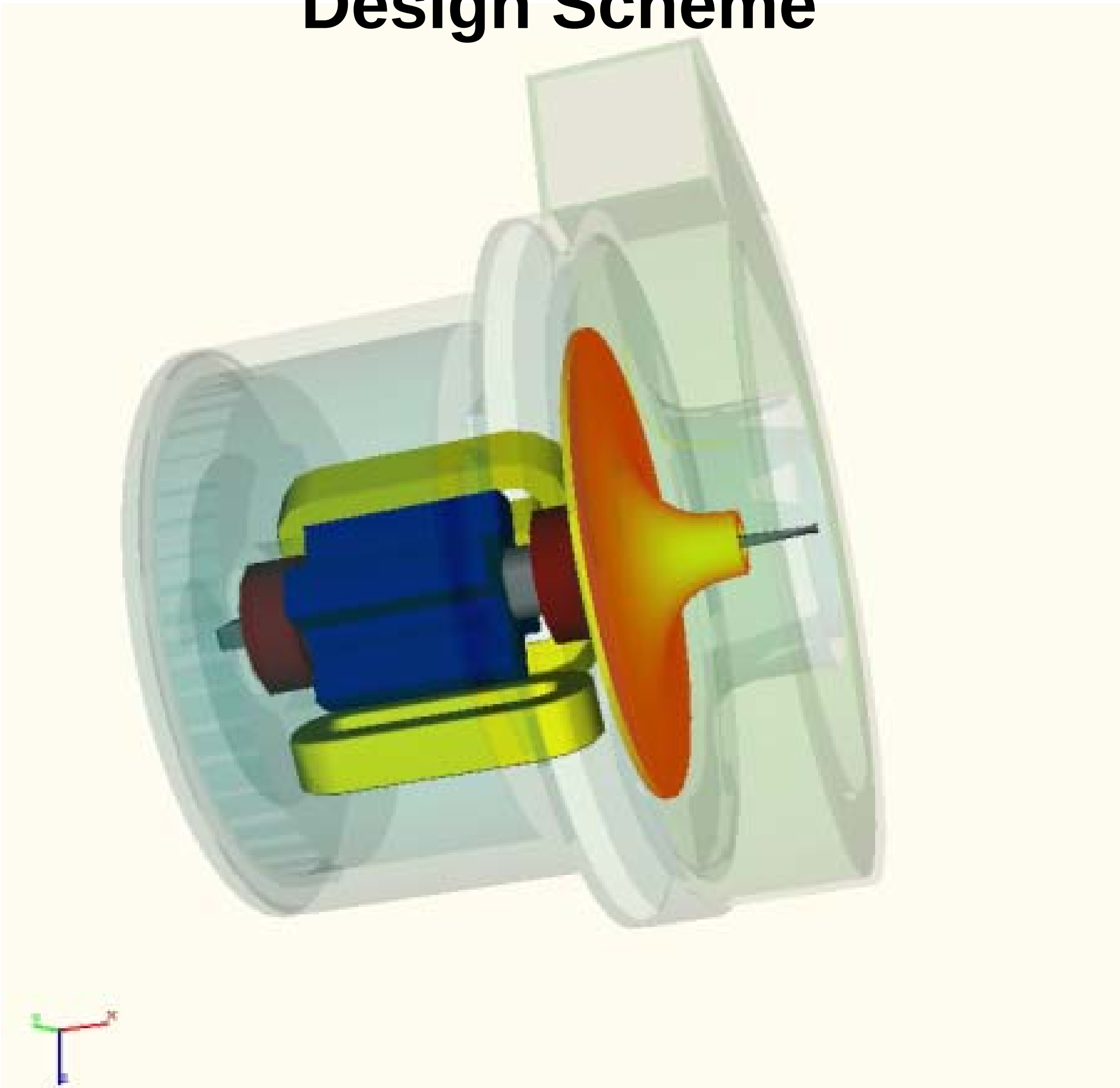
- Operating speed 80 – 90k RPM
  - Maximum shaft power ≈6kW.
- Voltage studies carried out for 12Vdc and 340Vdc
  - 12Vdc system selected for POC.



Design Challenges

- Need to maximise overall system efficiency.
- Electrical design needs to address problems posed by very high power throughput at low volts.
- Mechanical design needs to meet requirements of high speed operation at elevated temperatures.
- Thermal design needs to manage heating effects of machine & system power losses
  - High temperature coolant system
  - Very high exhaust gas temperatures

Design Scheme

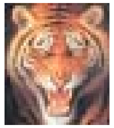


Risk

- Thermal
  - SR Machine windings, potting compound, power electronics
  - DGBB sealed for life grease pack
- Mechanical
  - Shaft critical speeds and rotor strength
- Cost
  - Additional cooling loop
  - Hardware cost down (POC to Prod. Intent Solution).
  - DC-DC converters and power electronics

Next Steps….

- Complete Mechanical & Electrical detailed designs.
- Expedite manufacture of POC hardware for Dec'05 (12v Dyno & 340v Rig).
- Complete Energy Cycle Simulation.
- Complete Vehicle Electrical System Design.
- Preliminary Control System Specification.
- Determine Feasibility of Total System Model.



Dissemination Opportunity

- Invitation to present a paper at the Hybrid vehicle conference held at Braunschweig University (Feb 2006).

  - Modelled comparison of series hybrid with gasoline engine

    - Engine only

    - Engine fitted with TIGERS (340V)

  - Compare results of distance achieved using the same amount of fuel

Any Questions ?