



# EV Drivetrain

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## *Background*

- An AutoCRC Visionary project
  - Lightweight Modular Vehicle Platform
  - Volume Efficient High Pressure Storage Vessel
  - **Electric Vehicle Drivetrain**
- AutoCRC acts as the industry partner
  - Goals
  - Timescales
  - Budgets



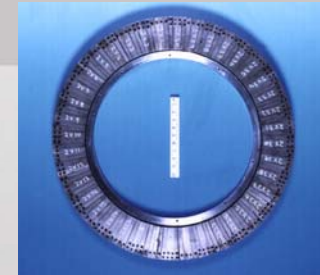
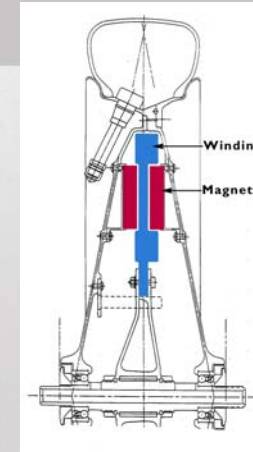
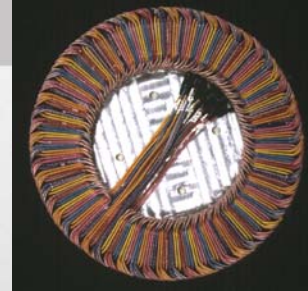
## *Aim*

- Develop a Cost Effective EV Drivetrain
  - Switched Reluctance Motors to reduce cost
  - In wheel for easy fitting to existing platforms
- Test on Bench
- Demonstrate in Vehicle
  - Barina Spark Donor Vehicle



## *In Wheel*

- Common in Solar Car Racing
  - Cost not an issue!
- Many Show Cars
  - Tellingly, *not* production vehicles



CSIRO/UTS/Newcastle/Aurora/Marand Solar Racecar Motor



Mitsubishi Colt EV (Wikipedia)



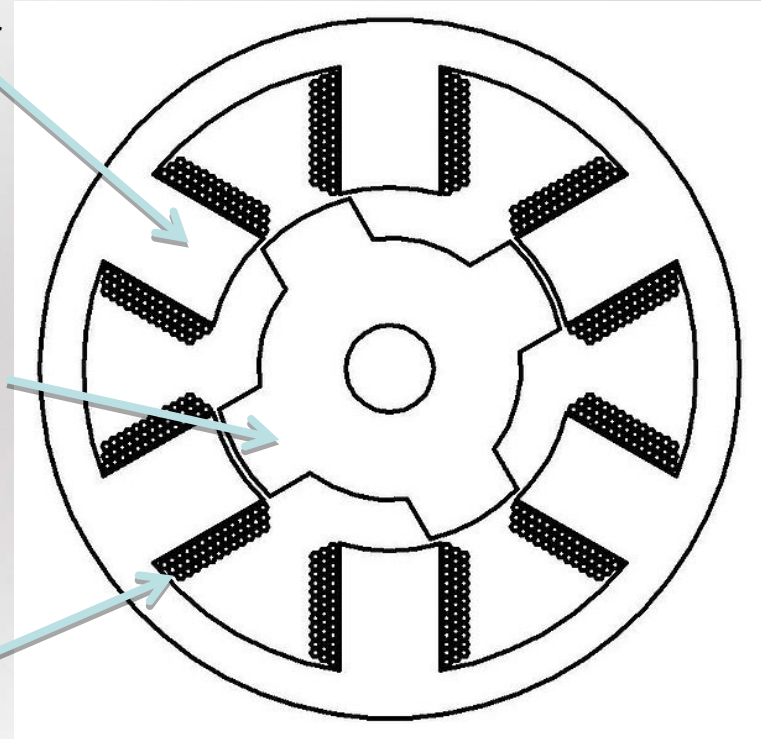
# Switched Reluctance (SR) Motor

- **Low Cost Motor**
  - No magnets
  - Simple winding
  - Robust
- **Low Cost Electronics**
  - Utilizes converter rating well
  - Field weakening

6 Pole Stator  
(2 poles  
per Phase)

4 Pole Rotor

Stator  
Winding



Example SR Motor



# Specification

Description	Symbol	Target	Description	Symbol	Target
Veh. mass	$m_v$	1,200 kg	Motor eff.	$\eta_m$	0.9
Rolling res.	$C_{rr}$	0.012	Motor mass	$m_m$	25 kg
Max. speed	$v_m$	39 m/s (140 km/h)	Max. grad.	$\theta_m$	0.2 rad (1 in 5)
Accel. time	$t_a$	16 s (to 25 m/s, 90 km/h)	Coeff. frict.	$\mu_m$	0.5
Acceleration	$a_a$	1.6 m/s <sup>2</sup>	Max. brake	$\tau_m$	-78 Nm (1/3 wheel lock)
Frontal area	$A_v$	1.5 m <sup>2</sup>	DC Volts	$V_n$	234 V
Drag coeff.	$C_d$	0.3	PF	$K_{pf}$	0.7
Rolling rad.	$r$	0.3 m (205/50R17 85N)	Motor cost	$K_{mc}$	0.1 US\$/Nm
# driven wh.	$n$	2 (rear)	Elec. cost	$K_{pc}$	0.016 US\$/VA
Elect. Eff.	$\eta_p$	0.9	Tor./kg	$K_{mm}$	17 Nm/kg



# Equations, Penalty, Constraints, & Unknowns

## Equations of motion

$$F_d = \frac{1}{2} \rho C_d A_v v^2 + m_v g (C_{rr} + \sin \theta)$$

$$F_t - F_d = m_v a$$

$$\omega = \frac{v}{r}$$

$$\tau = \frac{F_t r}{n}$$

$$P_m = \omega \tau$$

$$P_p = \frac{P_m}{\eta_m}$$

$$P_b = \frac{n P_b}{\eta_p}$$

## Penalty (cost)

$$c = K_{mc} \tau_m + K_{pc} \frac{P_p}{K_{pf}}$$

## Constraints

$$m_v g \sin \theta \leq \tau_m \leq m_m K_{mm}$$

$$v \geq a_a t_a$$

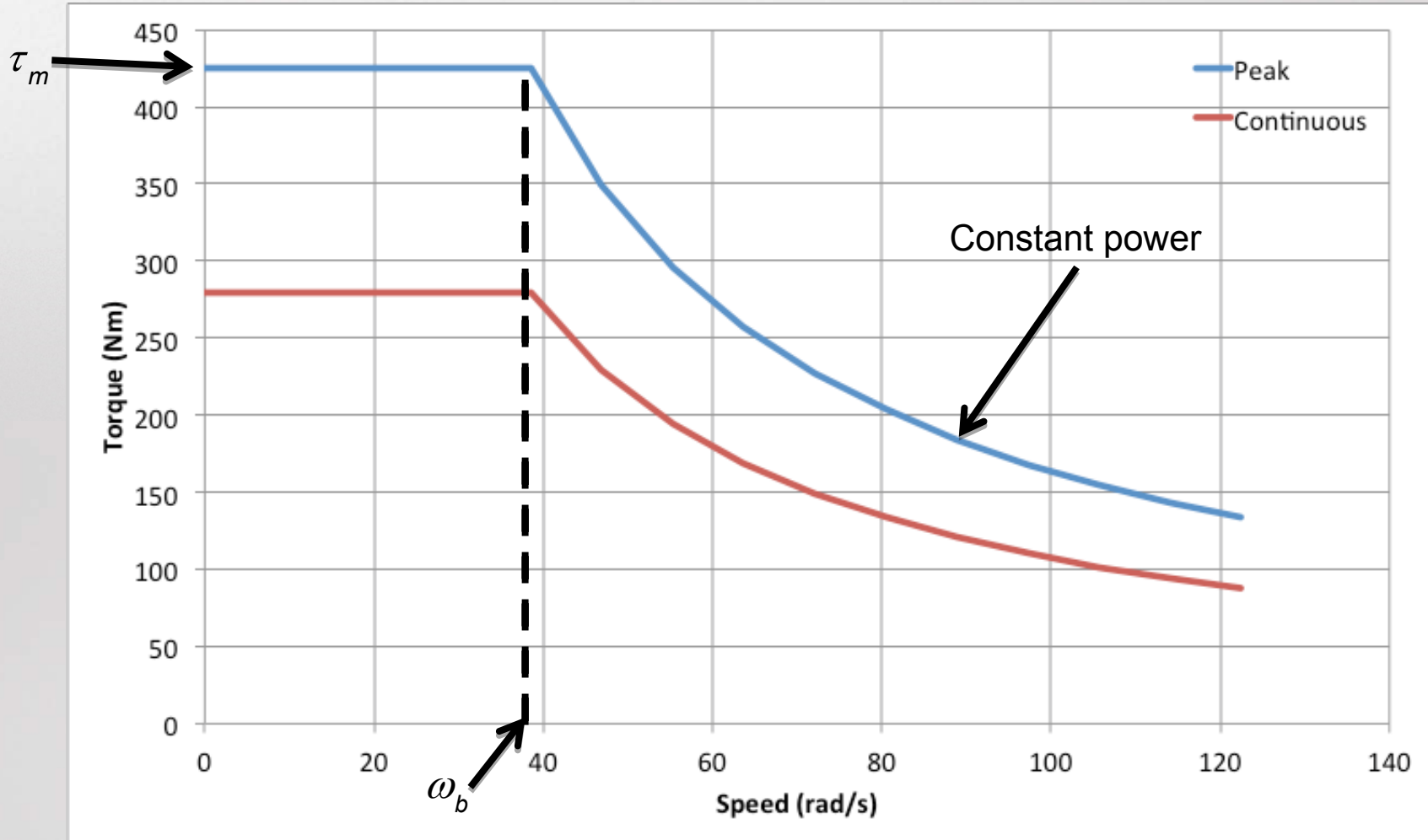
## Unknowns (define $\tau$ )

$$\tau_m$$

$$\omega_b$$

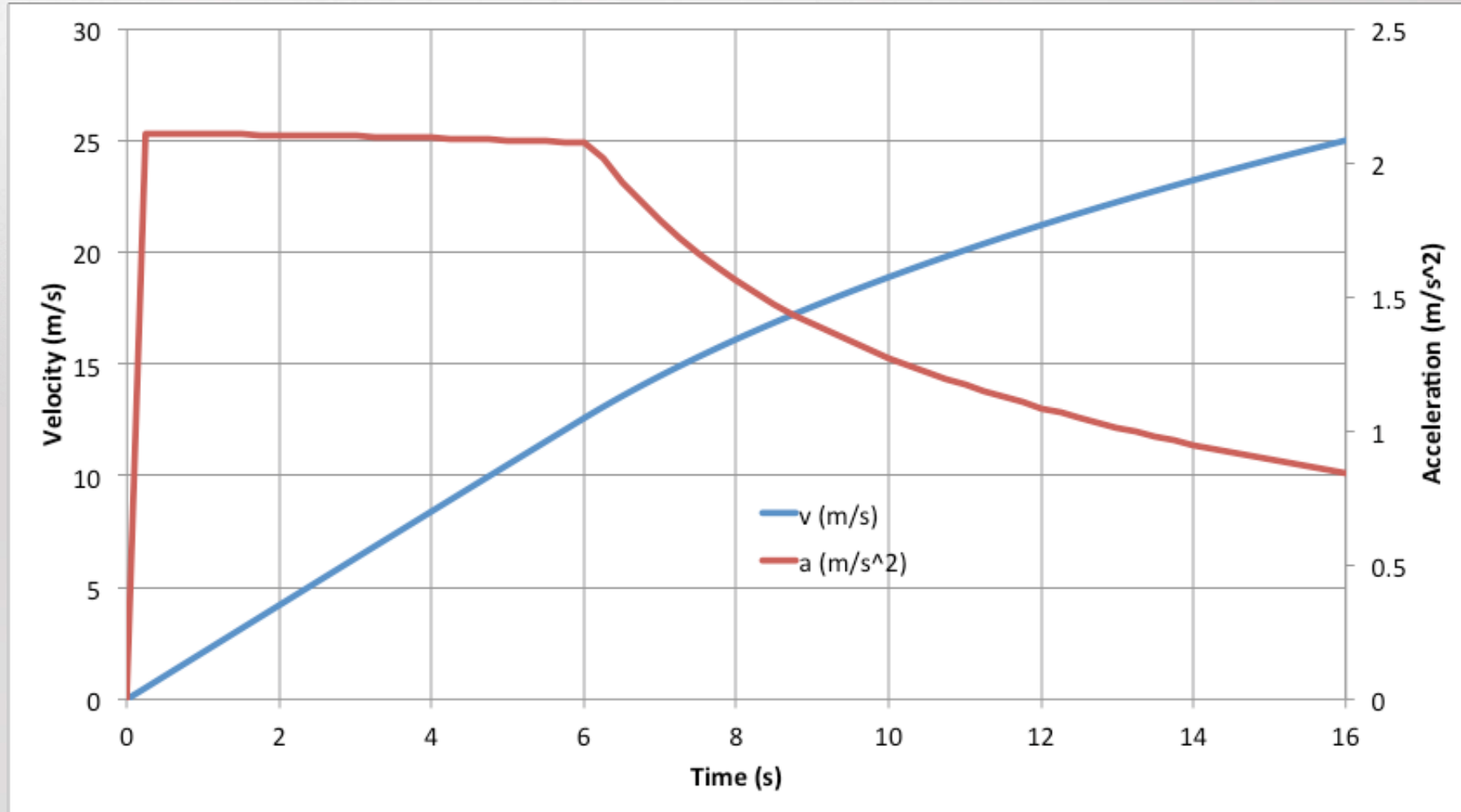


# Motor Torque ( $\tau$ )





# Numerical Solution





## *Optimum*

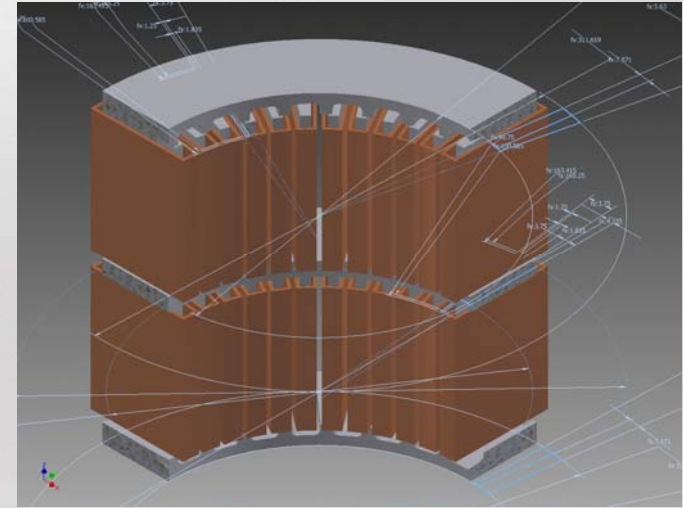
- $\tau_m = 425 \text{ Nm}$
- $\omega_b = 38.5 \text{ rad/s}$
- $c = 458 \text{ US\$}$ 
  - $c_m = 43 \text{ US\$}$
  - $c_p = 416 \text{ US\$}$

Costs are incremental costs (the component of cost effected by  $\tau_m$  &  $\omega_b$ )



# Motor Design

- SR Motor
- Double Airgap

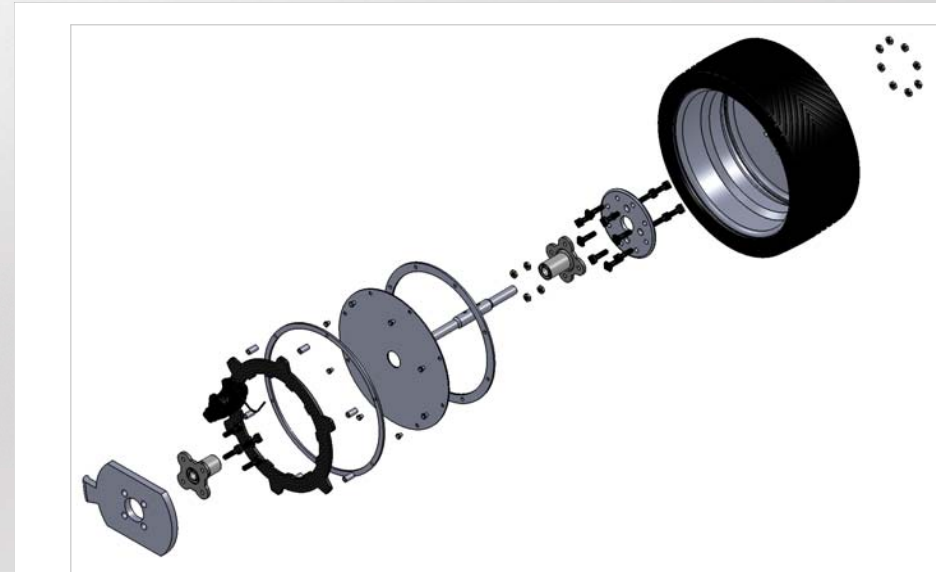


Motor design; quarter model view  
(not final dimensions)



# Wheel

- Integrated with motor
- Removable rim
- Incorporates disc brake

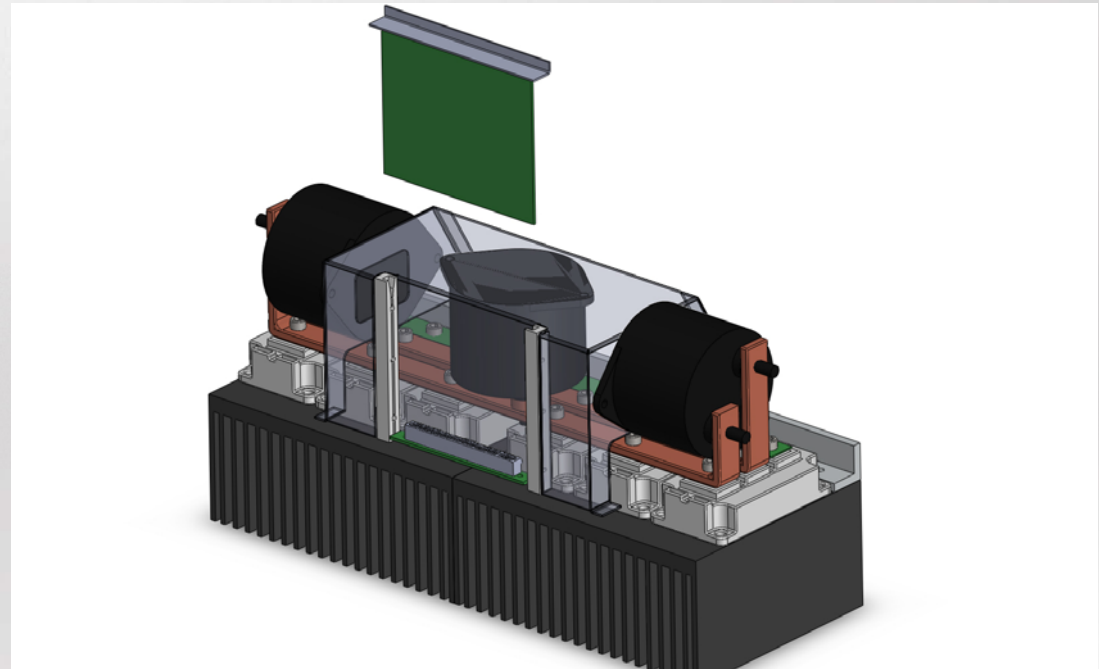


Exploded view of wheel; main parts only and not showing motor



# Motor Controller

- Field Programmable Gate Array
- Insulated Gate Transistors
- Power MOSFETs



Exploded view of power electronics; excluding case



## *Other Parts*

- **System Controller**
  - Monitors batteries
  - Interfaces vehicle to motor controllers
  - Monitors wheel-speed difference (safety)
- **Battery pack**
  - LiFeMnPO<sub>4</sub>, 72 Cells, 100 Ah / cell
- **Vehicle**
  - Holden Barina Spark
  - Rear wheel drive (2 driven wheels)



## *Synopsis*

- Difficult specification
  - Cost & mass
- Optimization Outlined
- Main components described
- Next
  - Build & bench test
  - Convert donor vehicle & in-vehicle test
- Full paper IECON'11 Melbourne

