High Efficiency Permanent Magnet Motor

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Background

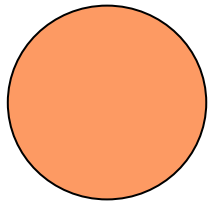
- CSIRO, the Commonwealth Scientific and Industrial Research Organisation, is Australia's national science agency and one of the largest and most diverse research agencies in the world.
- CSIRO has extensive capability in the area of electric machine design, Marand has collaborated with CSIRO on a number of projects including the commercialisation of high efficiency permanent magnet motors, and Switched Reluctance Electric motors.
- CSIRO designed a high efficiency Permanent Magnet Axial Flux In-Wheel Motor in conjunction with Aurora Solar Car Team in 1997
- CSIRO has licensed the design to Marand. In partnership with CSIRO we are further developing the technology for a number of new applications with rapidly growing global demand

Motor Materials

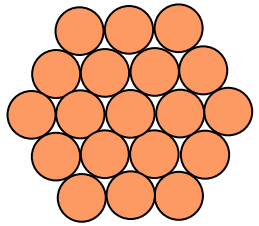
- Each magnet ring consists of 40 neodymium-boron-iron rare earth magnets. Total of 80 magnets per motor
- There is approximately 40 metres of Litz wire per motor across the three phases.
- The Litz wire is a multi-strand wire, the individual stands have a rectangular section and have approximately 340 stands per wire.
- Litz wire is used to reduce the “skin effect” of the wire – impact on the wires impedance to high frequency AC current, the use of Litz wire utilises the full cross sectional area of the wire to carry current due to the individual strands being thinner than the skin depth. The wire is also twisted and woven for similar reasons

Wire Cross Sections

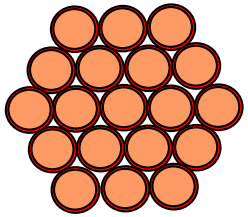
- Solid Core



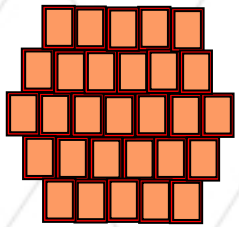
- Multi-strand



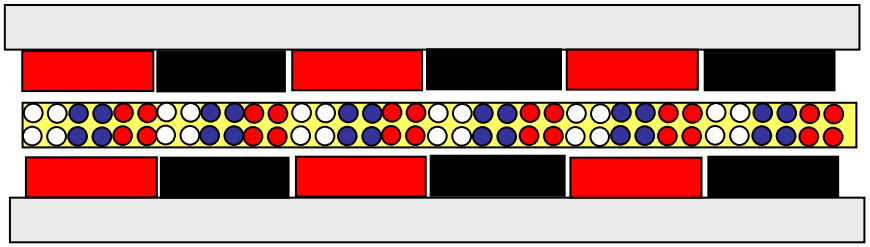
- Insulated multi-strand circular section Litz wire



- Insulated multi-strand rectangular section Litz wire, actually compacted round wire



The Stator

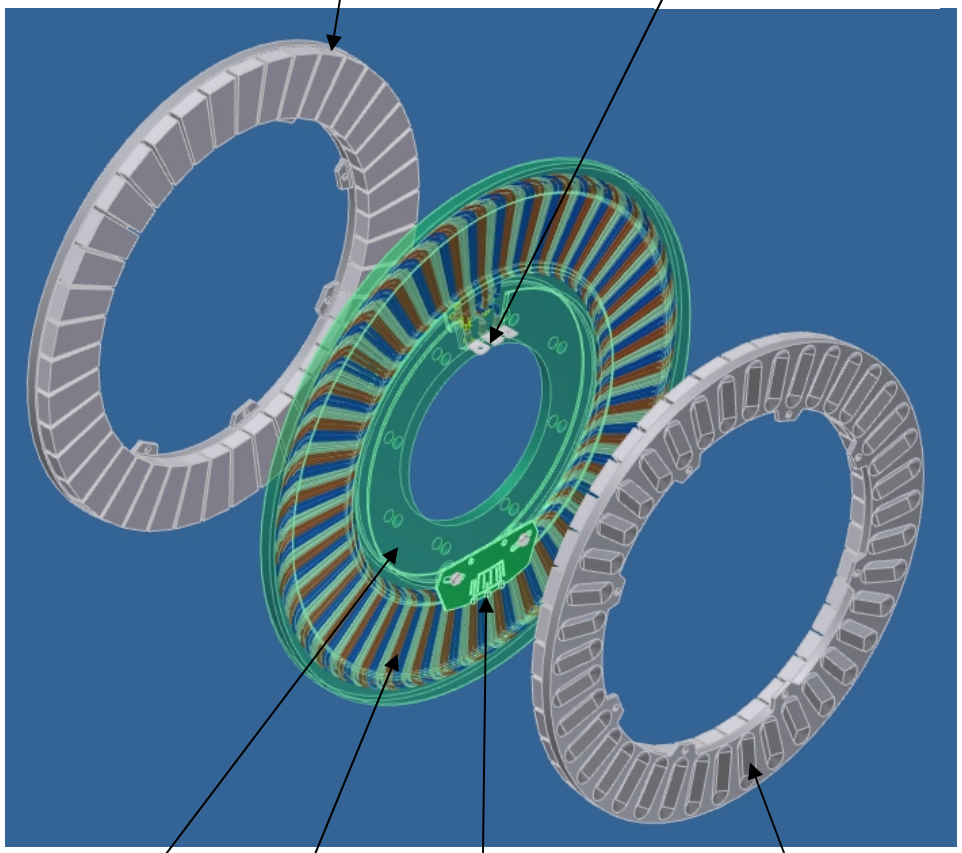


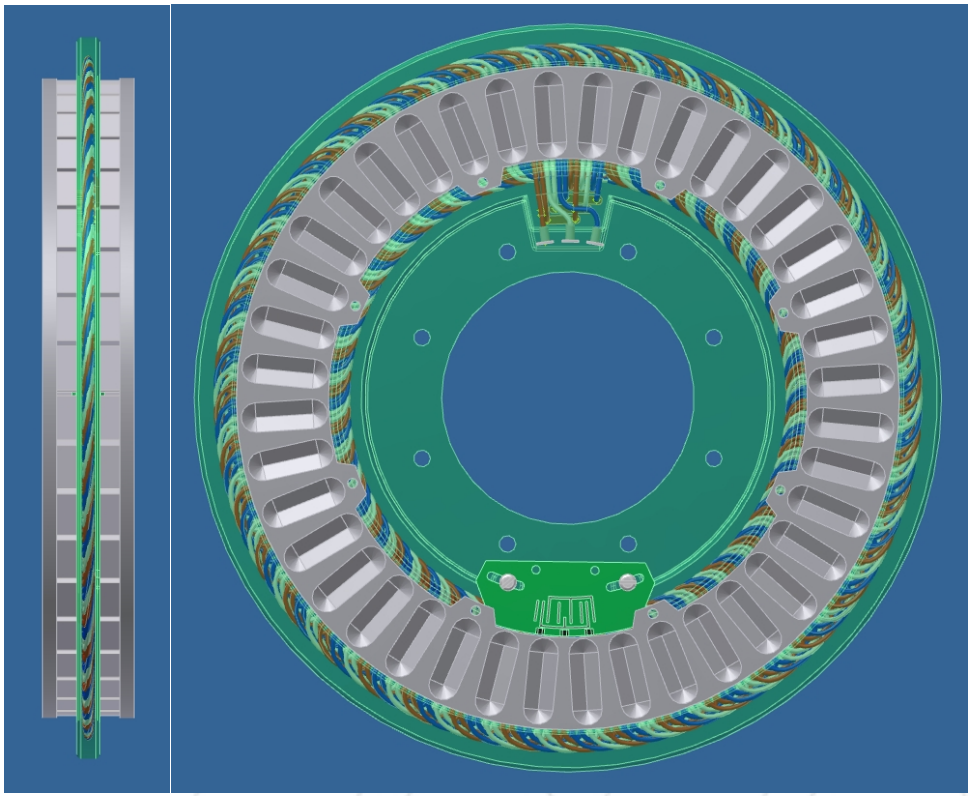
- 6 Windings for 3 phases allowing series or parallel wiring giving flexibility with operating voltage
- Each phase is repeated 40 times
- The windings are configured to so that all conductors of a given phase have there current flowing in the same direction
- There a 3 phases in the width or a single magnet.
- Approximately 40 hours labour to wind a single stator

Magnet Assembly

- Two assemblies per motor
- 40 magnets per assemblies, total 80 per motor
- Air gap between assemblies is 10.9 mm
- Resultant air gap to stator is1.75 mm nominal
- At assembled air gap there is approximately 5kN of force pulling the magnets together
- If the magnet assemblies should come in contact the force is approximately 20kN

Motor Overview





Multiple Motor assemblies can be Stacked in “Pancake” configuration to meet specific power needs

Note: Single Motor Assembly shown

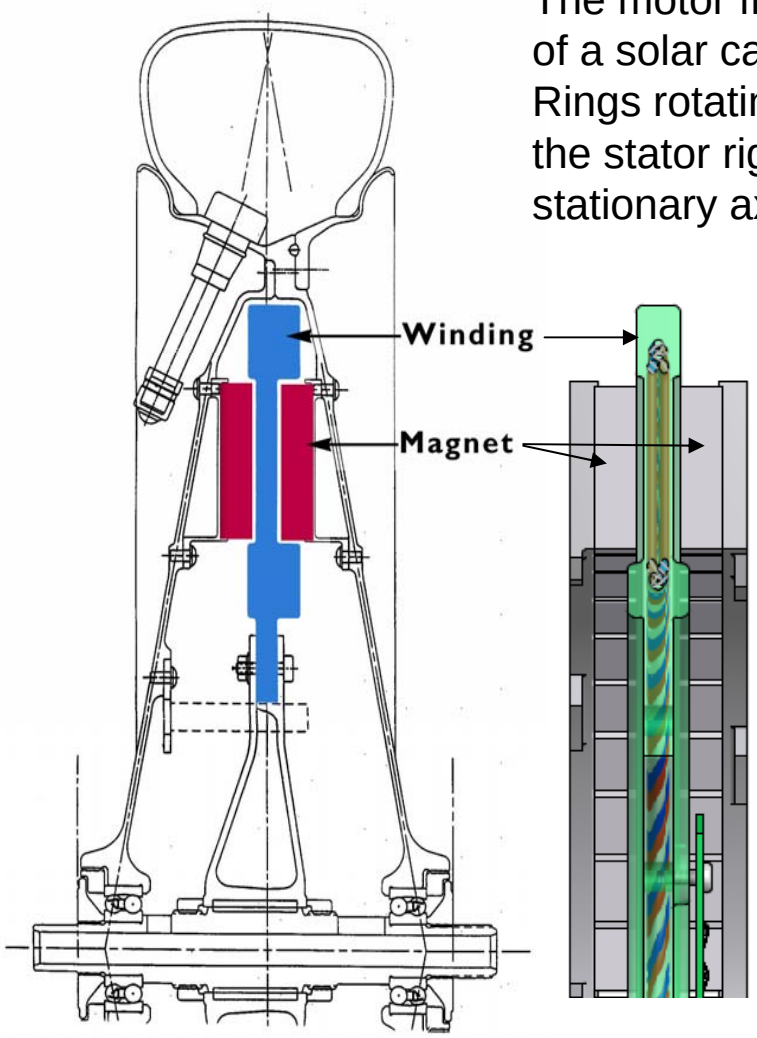
Comparison of Solar Car Motor against other Motors

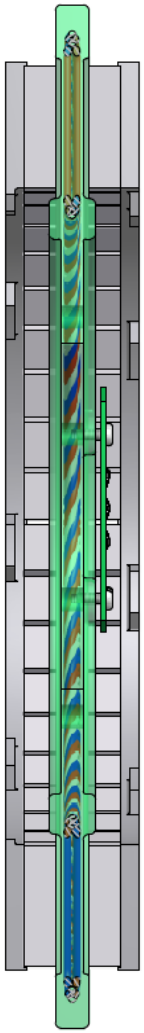
	Torque to total weight ratio (Nm/kg)	Torque to total volume ratio (Nm/m^3)	Efficiency (%)	Losses (%)
Solar Car Motor	3.61	10135	97.3%	2.7%
Typical 30Nm Induction Motor	0.80	1500	82%	18%
Internal Combustion Engine	1.5	1970	25%	75%

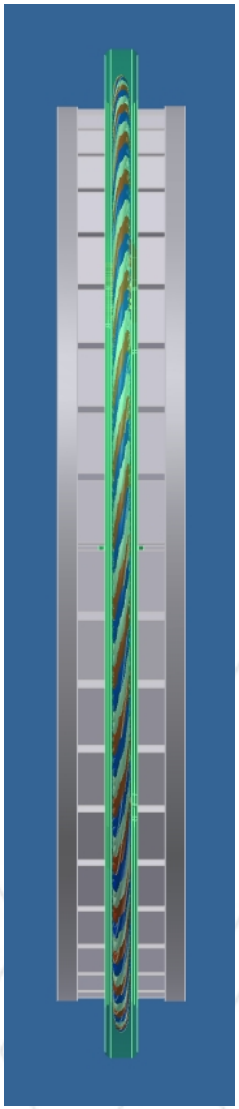
Source: Design of an In-Wheel Motor for a Solar-Powered electric Vehicle; H C Lovatt, V S Ramsden, B C Mecrow; 1997

The Motor

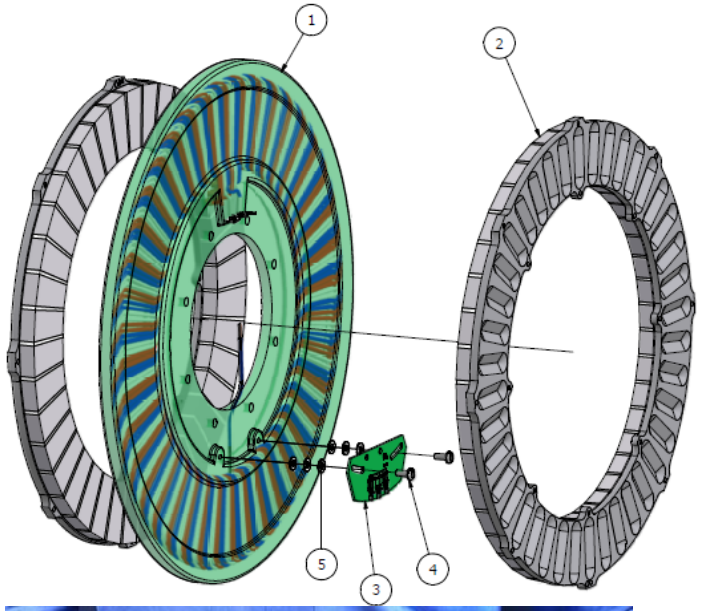
The motor fits within the wheel of a solar car with the two magnet Rings rotating with the wheel and the stator rigidly fixed to the stationary axle.

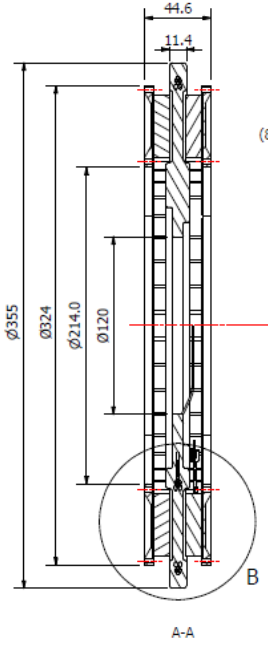


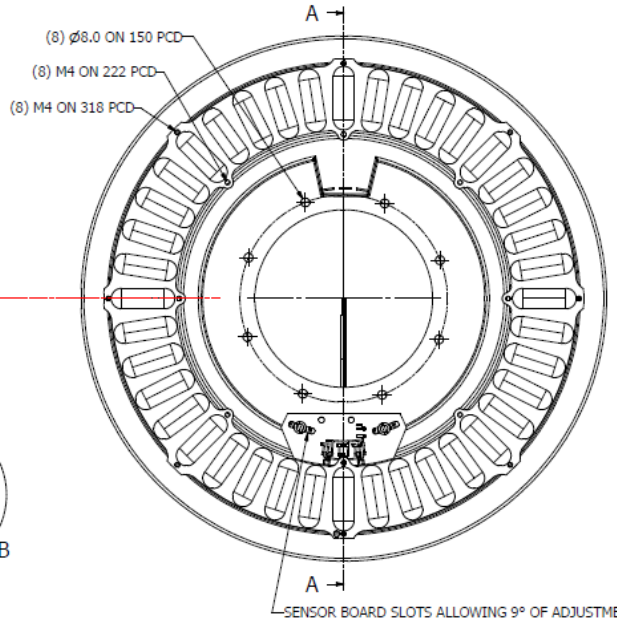


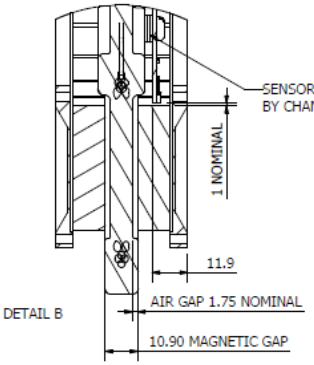


Single Motor Size









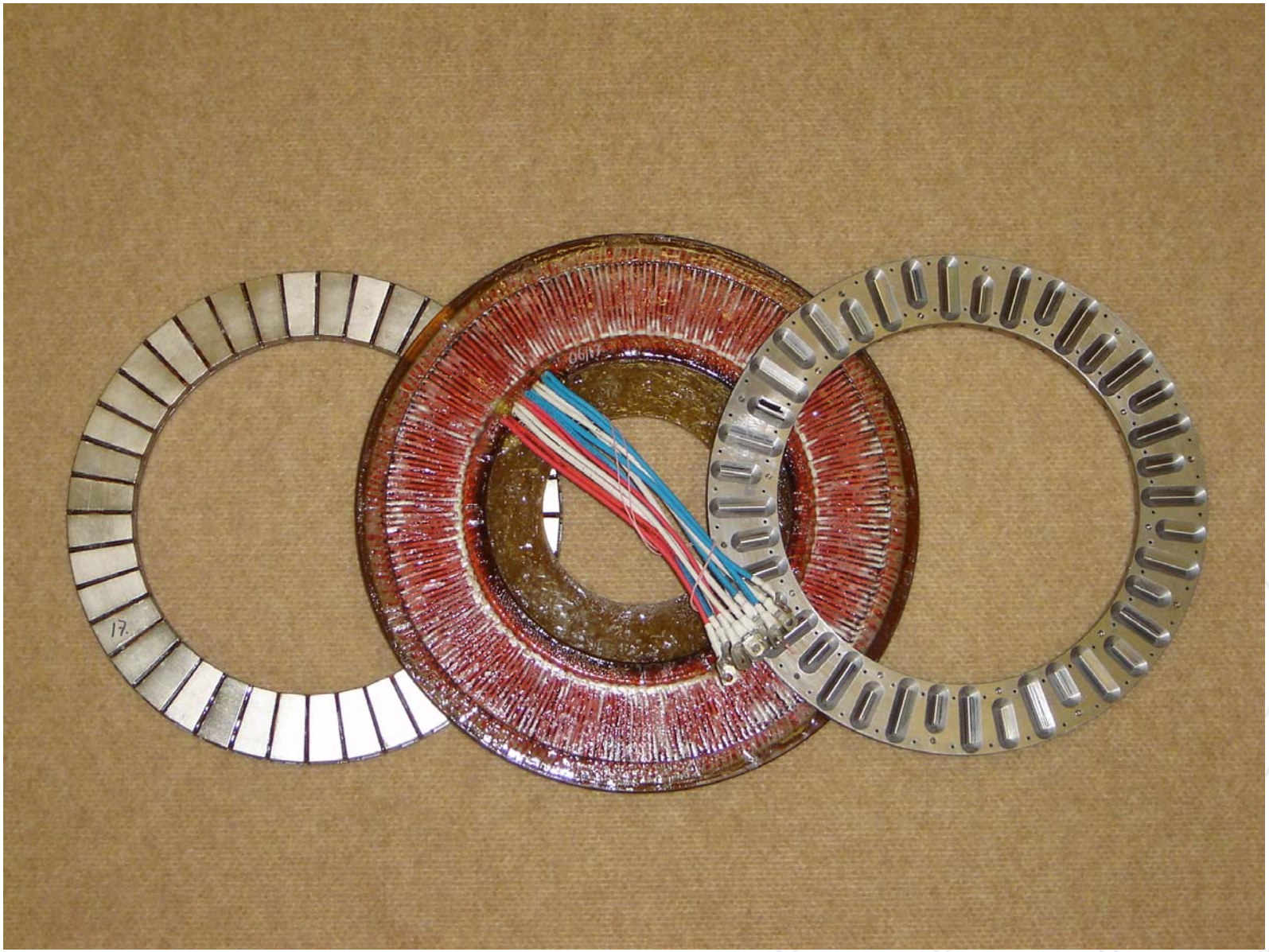
WARNING!
FORCE OF ATTRACTION BETWEEN MAGNET RINGS IS 4966N WHEN 10.9mm APPART

GENERAL FORMULA F ~ 6.4/(0.025+d)^2

WHERE F = FORCE (N)
D = MAGNETIC GAP (m)

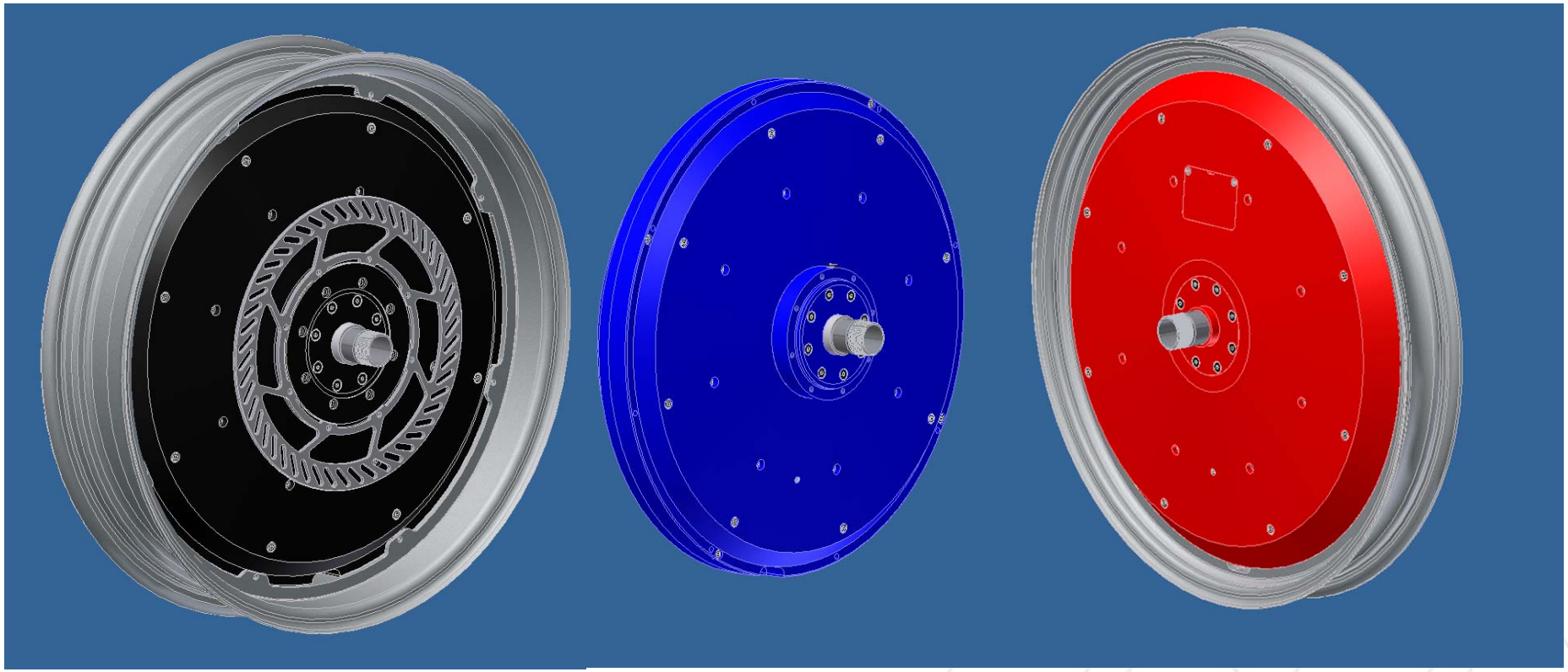
SOLAR CAR MOTOR PROJECT				Q8153	SCM STEEL-BACK
STEEL-BACK KIT MOTOR ASSEMBLY				MARAND PRECISION	A2

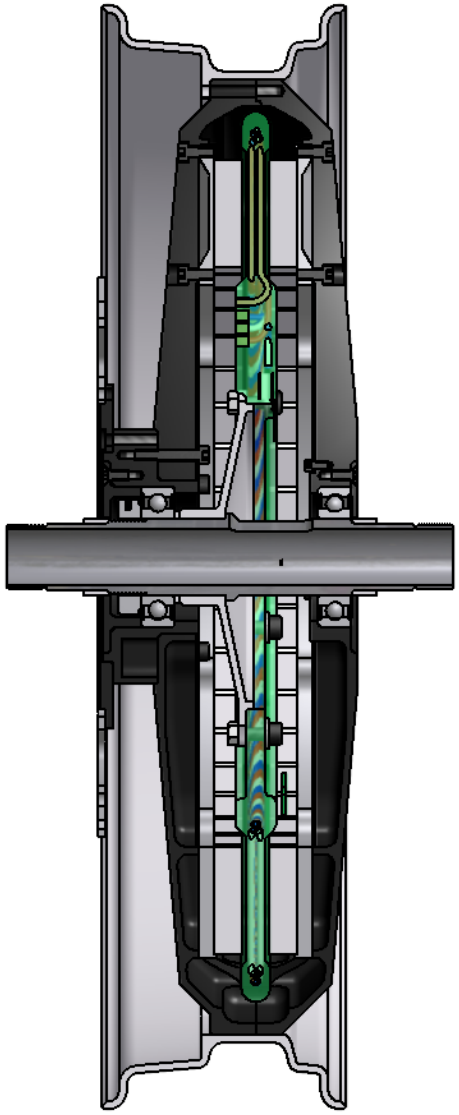
Steel Back Kit



Wheel Views

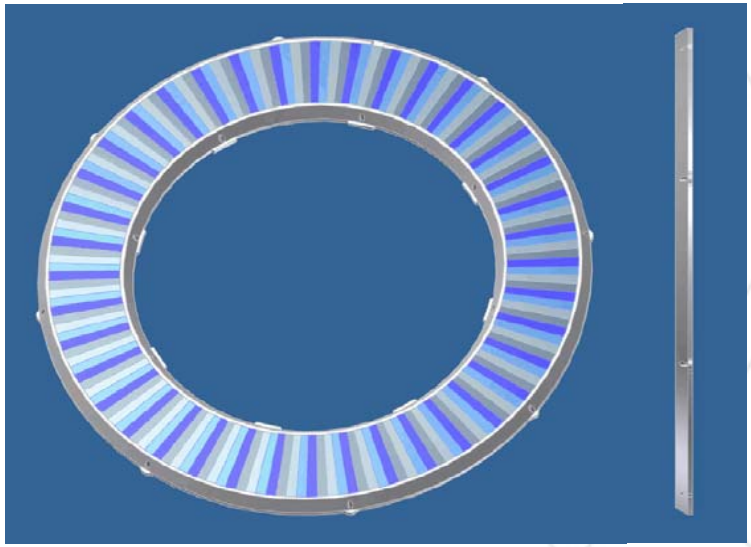
- Can be anodised in various colours





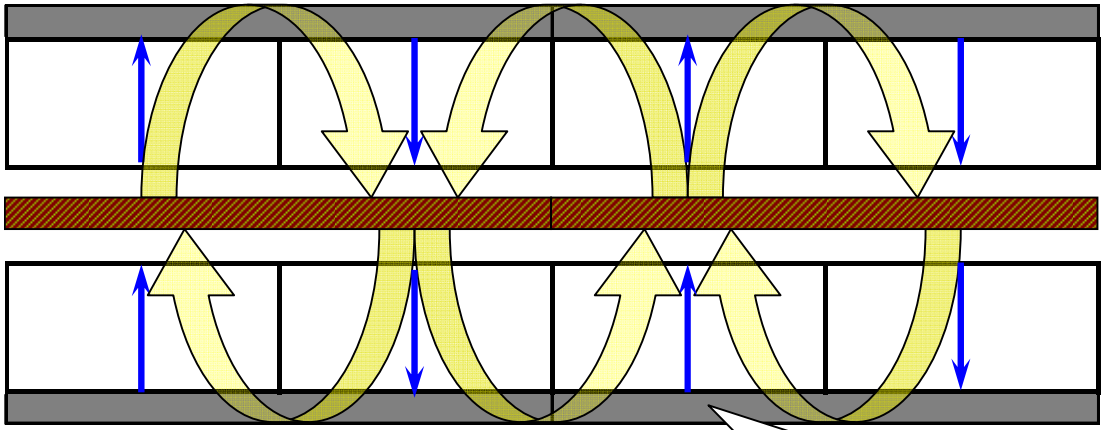
Product Overview - Halbach Magnet Ring

- A Halbach magnet array uses multiple individual magnets (3 per pole) with different North/South pole orientation to create each pole.
- A Halbach therefore has 120 magnet of 6 types compared to a steel back which has 40 magnets of 2 types
- The Halbach design delivers a better magnetic flux path which means compared to a steel back the halbach can;
  - Make the same torque with less current, or
  - More torque with same current
- The Halbach is also significantly lighter as no steel backing plate is required to create the magnetic flux path.

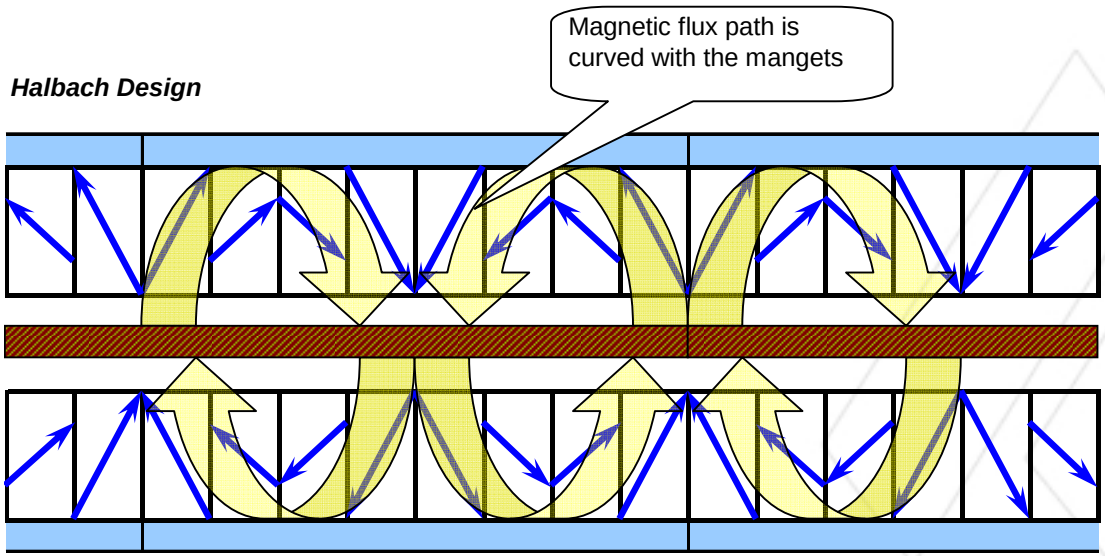


Product Overview - Halbach 4 Magnet Ring

Steel-back Design



Halbach Design



Benefits of Marand Motor

- High Efficiency – Marand offers up to 98.4%, in the ultra competitive area of solar car race motors competitors are offering <95%

- Low mass - Halbach variant 7kg, competitors offering in the range of 11 – 20 kg.

- CSIRO / Marand motor can be configured for operation with series or parallel windings in the stator giving flexibility with motor controllers

Background

- Marand has two versions of this motor including a new Halbach design that has not been previously released.

	Steel-Back	Halbach
Rated Power	1800 W	1800 W
Continuous Power	4 kW	5 kW
Peak Power	10 kW	12 kW
Efficiency	97.3%	98.4%
Mass	10	7

Notes:

Mass consists of stator and two magnet rings

Efficiency is at rated power

Thank you