

Bridging the gap

Pathways for Transport in the Post 2012 Process



Flywheel energy storage for transport applications

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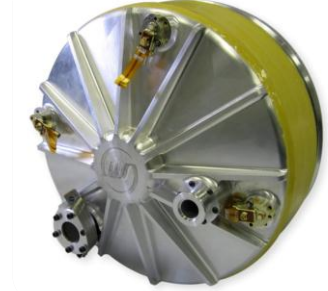
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Kinetic Energy Recovery System (KERS)

- System introduction due to FIA regulation change announced 2006
 - Allowed from 2009
 - 400 kJ per lap
 - 60 kW max. power
- Technology choice for teams
 - Chemical batteries
 - Ultra-capacitors
 - Flywheels (mechanical or electrically coupled)



Technology Comparison



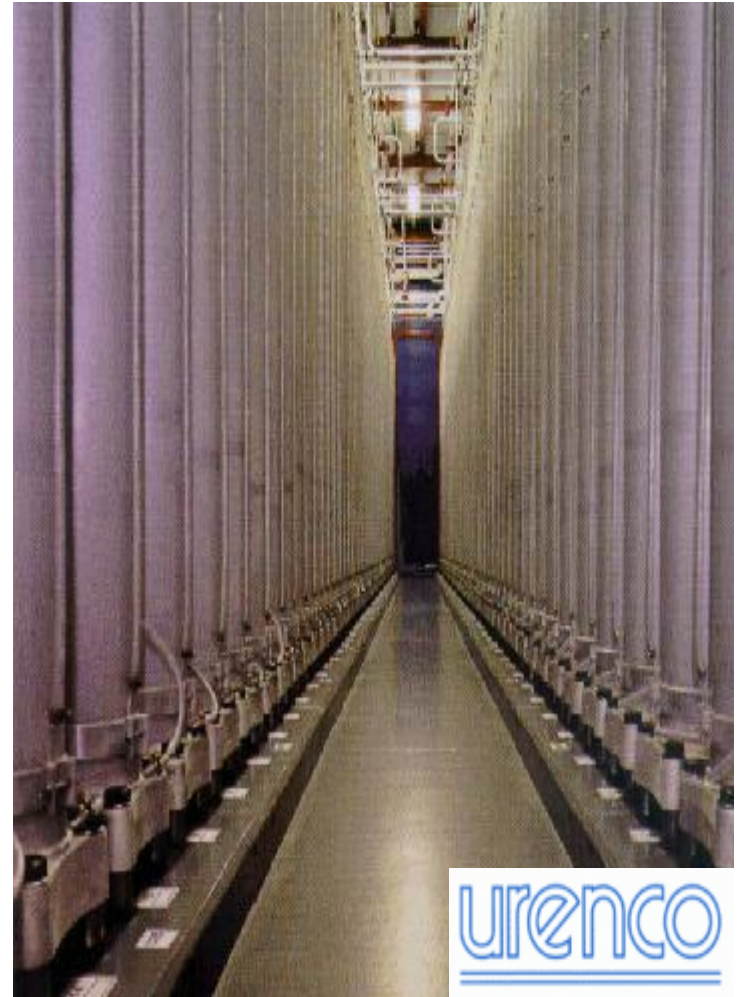
	A123Systems ANR26650M1 cell¹	Maxwell BMOD0063- 125V Ultracapacitor²	Williams' electromechanical flywheel
Specific Power (continuous)	0.15 kW/kg	0.32 kW/kg	3.00 kW/kg
Specific Energy	390 kJ/kg	11 kJ/kg	33 kJ/kg
Weight to achieve 120 kW (continuous cycling) power	233 kg	375 kg	40 kg
Cycle life (charge/discharge cycles)	<10,000	~1,000,000	~10,000,000

¹ http://a123systems.textdriven.com/product/pdf/1/ANR26650M1_Datasheet_AUGUST_2008.pdf

² http://www.maxwell.com/pdf/uc/datasheets/20090130_DATASHEET_BMOD0063_1014696.1.pdf

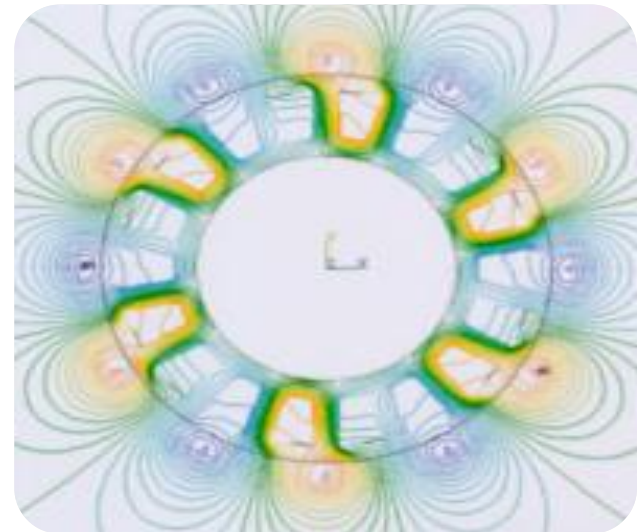
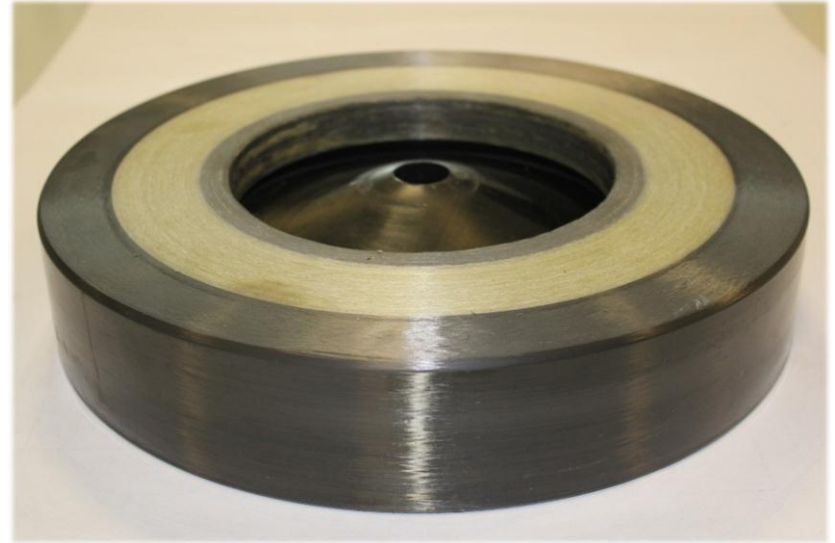
Technology Background – Urenco

- Uranium enrichment using gas centrifuges
- Design and manufacture since 1960's
- Ultra high speed composite centrifuges
- >500,000 centrifuge systems operational
- Design life greater than 15 years with zero-maintenance bearing systems.
- First generation machines still running after more than 20 years



Magnetic Loaded Composite (MLC)

- Technology
 - Magnetic powder in composite
 - Impulse magnetised
 - Patent protected
- Advantages
 - Very high continuous symmetric power density
 - Sufficient energy capacity
 - Long charge/discharge cycle life
 - Insensitive to ambient temperature
 - Manufactured using mature mass-production processes
 - Non-toxic construction resulting in low-cost recycling at EoL



Regenerative Braking – How does it work?



Williams' Flywheel Energy Storage Products

Mobile System

- 1.8 MJ / 120 kW



Stationary System

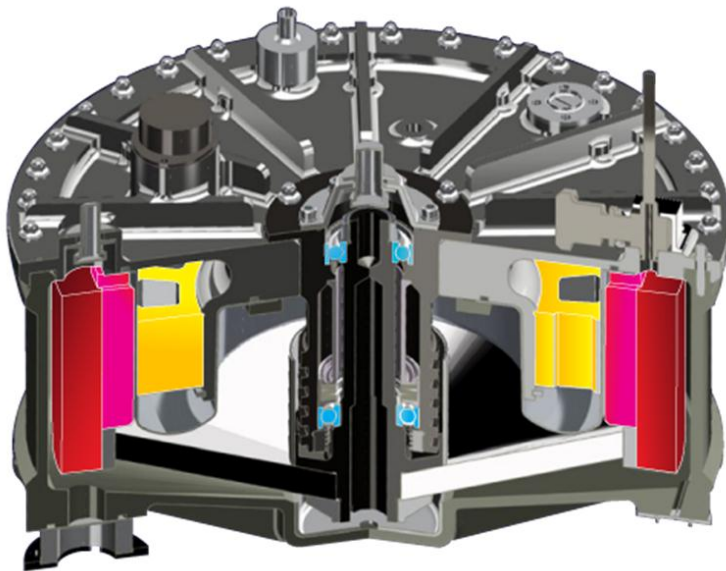
- 5.5 MJ / 200 kW



Williams' Flywheel Construction

Mobile System

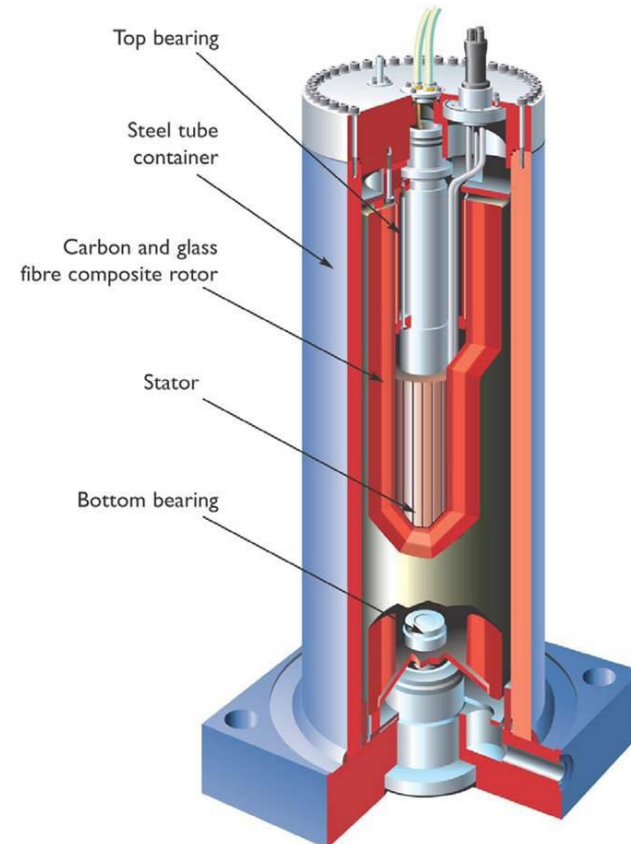
- MLC rotor
- Ceramic bearings



- Carbon fibre
- Stator
- Ceramic bearings
- MLC

Stationary System

- MLC rotor
- Magnetic and pin bearings



Bus Application (Mobile)

- Working with Go-Ahead to develop and produce six prototype London buses with a retrofitted mobile hybrid flywheel system
- 30% improvement in fuel economy
- The average bus produces 77-100 tonnes of CO₂ per annum. The hybrid system reduces CO₂ by 15-20 tonnes of CO₂ per annum

Gyrodrive one gallon



Standard bus one gallon



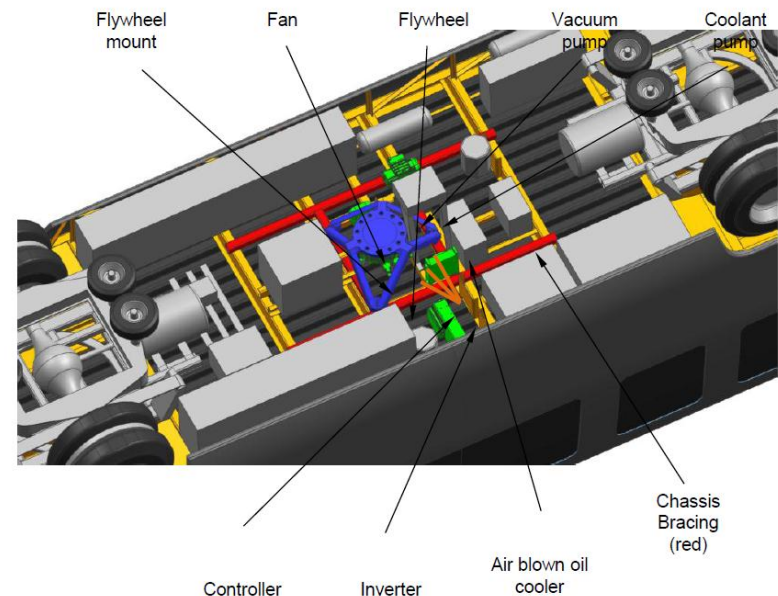
Mass Transit Application (Stationary)

- Williams stationary flywheel systems installed at the Bombardier test track in Canada
- Energy savings, emergency reserve, and voltage support testing and evaluation
- The flywheels were able to capture, store, and regenerate 100% of the available braking energy
- Up to 16% energy savings



Mass Transit Application (Mobile)

- Automated people mover (APM) hybridisation study using mobile flywheel
- One mobile flywheel system required per car
- Up to 19% energy saving calculated from actual energy measurements
- Equivalent to 120.9 tonnes CO₂e reduction per year





Buses



Refuse Collection Vehicles



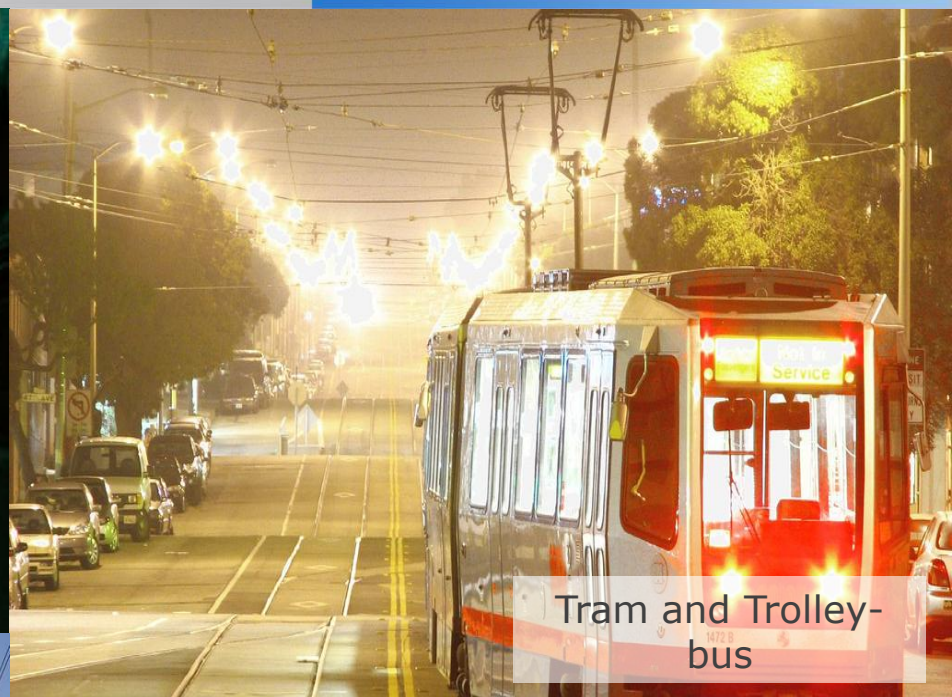
Light Commercial Vehicles



Off-Highway Vehicles



Metro Rail



Tram and Trolley-bus



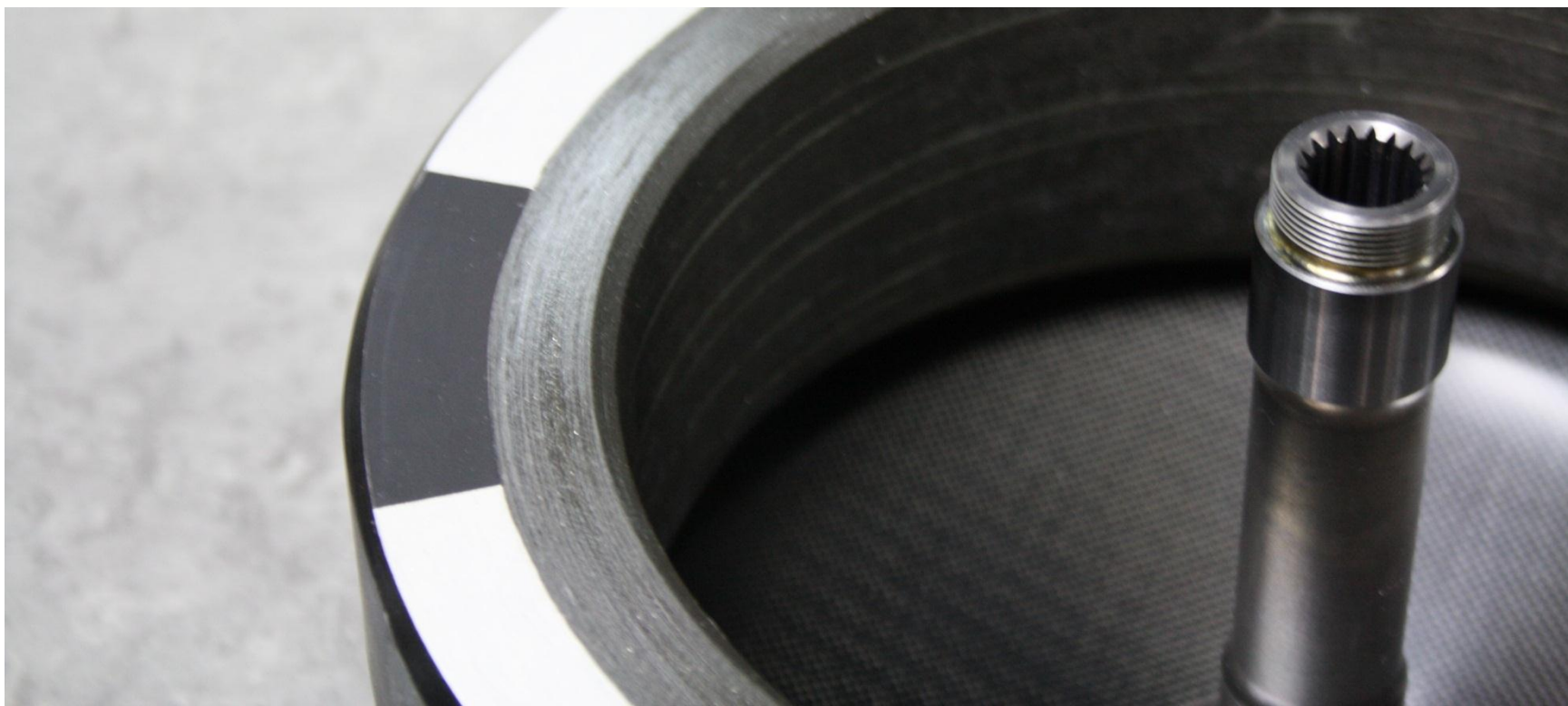
Electricity Grid



Renewable power



ADVANCED ENGINEERING



Thank You