

*“An integral partner in the delivery of outstanding
powertrain into future vehicles”*

∫ integral powertrain

VR-Pulley Micro Hybrid

IP VR-Micro Hybrid Systems

IP VR-Pulley (1)

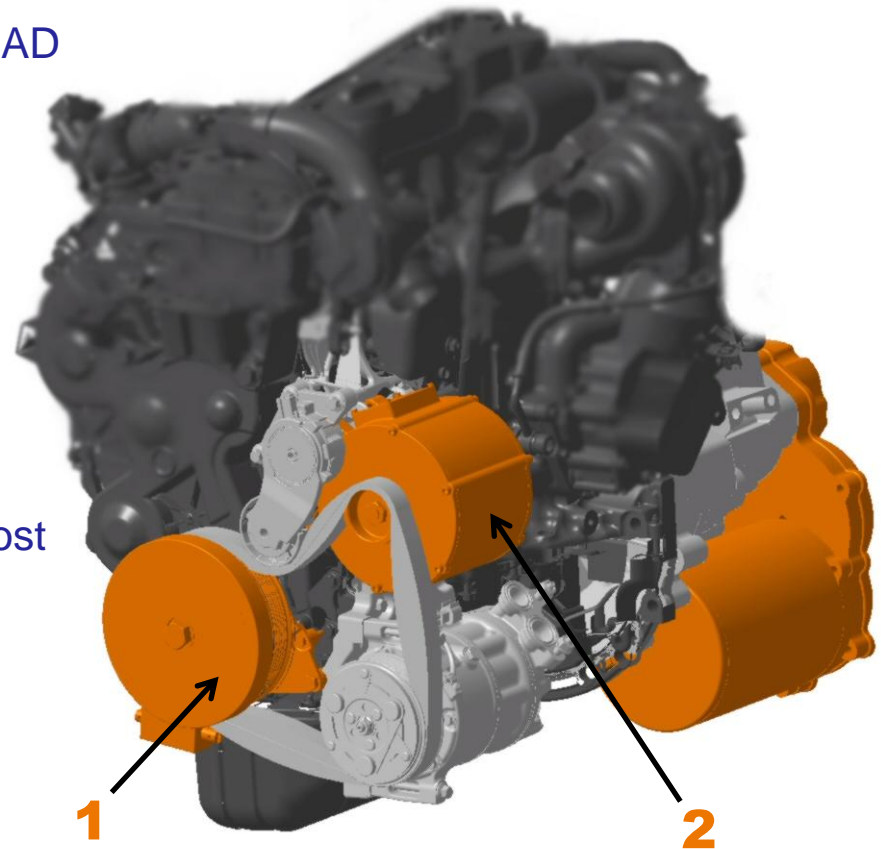
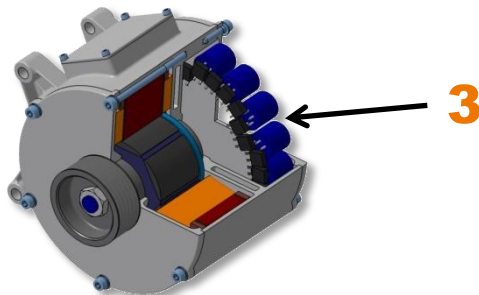
- Engine cranking with 3:1 ratio in pulley
- Engine stop neutral drive – for HVAC, PAS, Vac Pump etc. etc.
- Passive 1:1 drive for engine drive of FEAD
- Low tension FEAD belt system
- One low power solenoid actuator

IP BSG Machine (2)

- Low torque / high speed configuration
- Reduced current demand
- Reduced mass & cost

SPS Smart Power Electronics (3)

- Dual voltage architecture for reduced cost
- Innovative motor back EMF handling



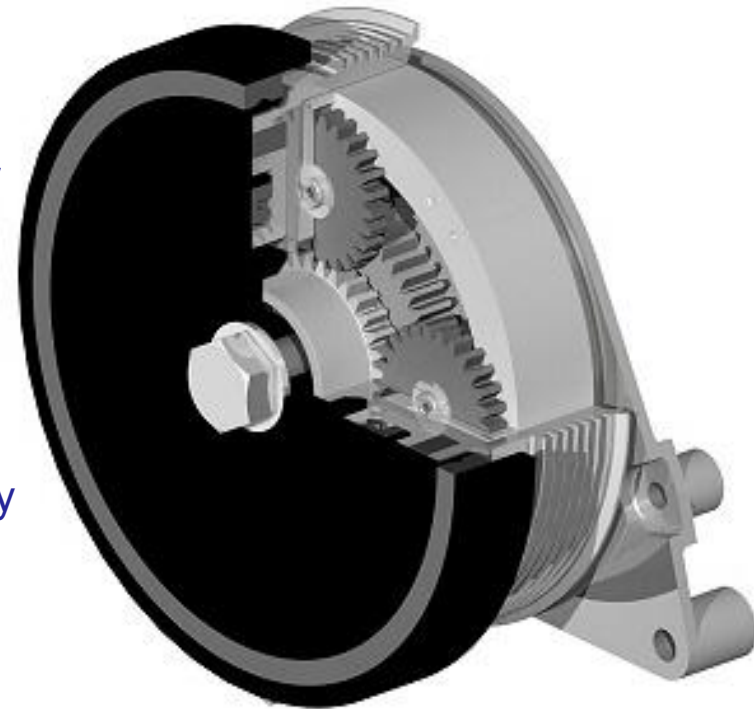
Variable-Ratio Crank Pulley

Concept

- Single 2-position solenoid actuator gives two speed ratios plus neutral - 1:1 / 3:1 / N
- Minimal impact on package – fits in conventional pulley diameter; includes integrated T.V. damper
- Designed to integrate with low-cost Hi-speed Belt Starter-Generator in place of alternator
- Simple spur gears (no ring gears), integrated de-coupler function and robust design
- Low actuation forces

Benefits

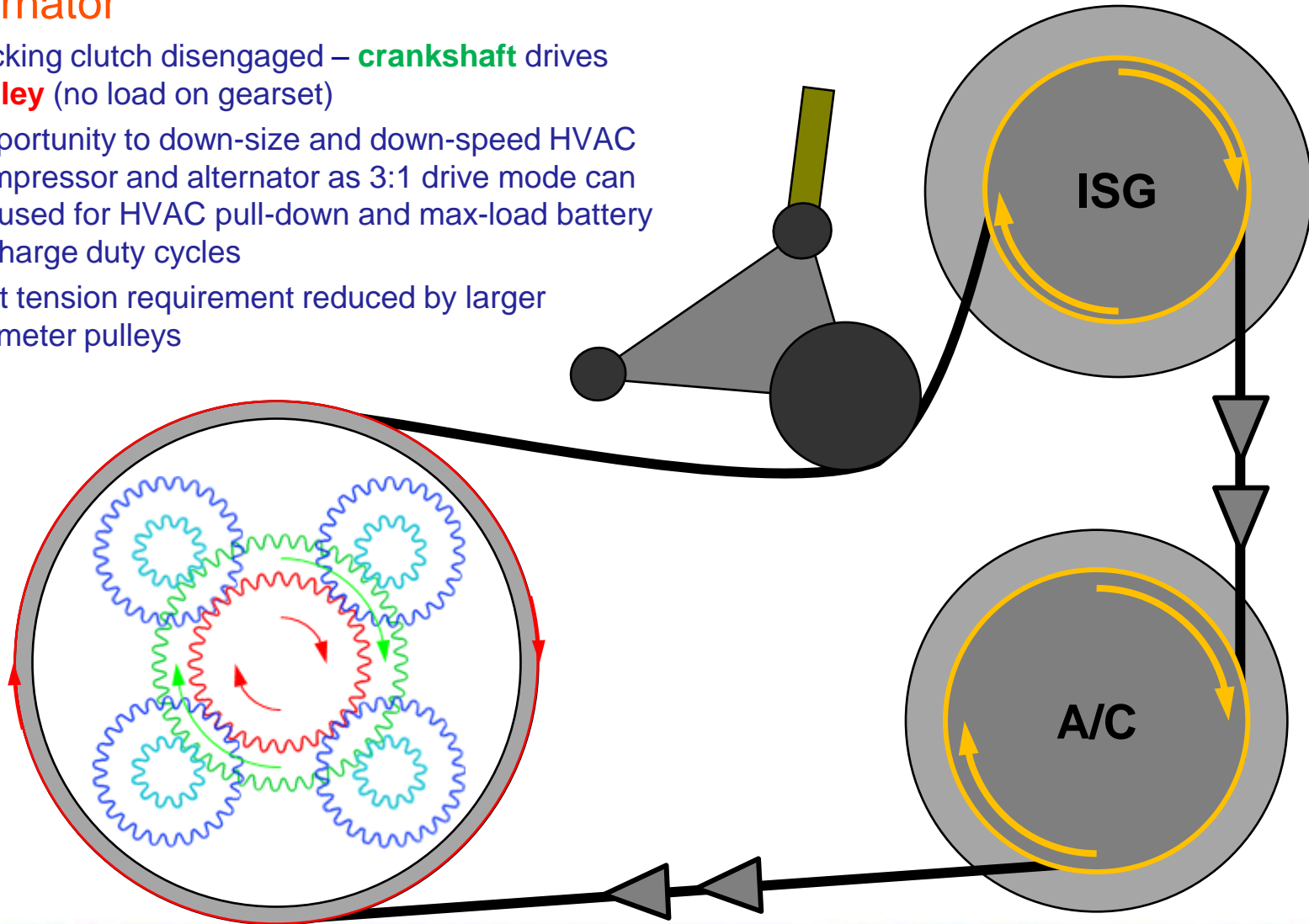
- **Lower BSG torque** – reduces e-machine / inverter and battery cost and package – also enables use of high eff'y IPM machine
- **Electric ancillary drive (EAD)** available for engine-off operation of HVAC and other systems
- **Reduced belt tension** – reduced belt losses, bearing loads & FEAD system cost
- **High ratio FEAD drive mode** - for use at idle & low engine speeds to reduce mass/cost & parasitic friction of Alternator/BSG and HVAC



1:1 Conventional Drive Mode

1:1 low-friction drive for HVAC and Alternator

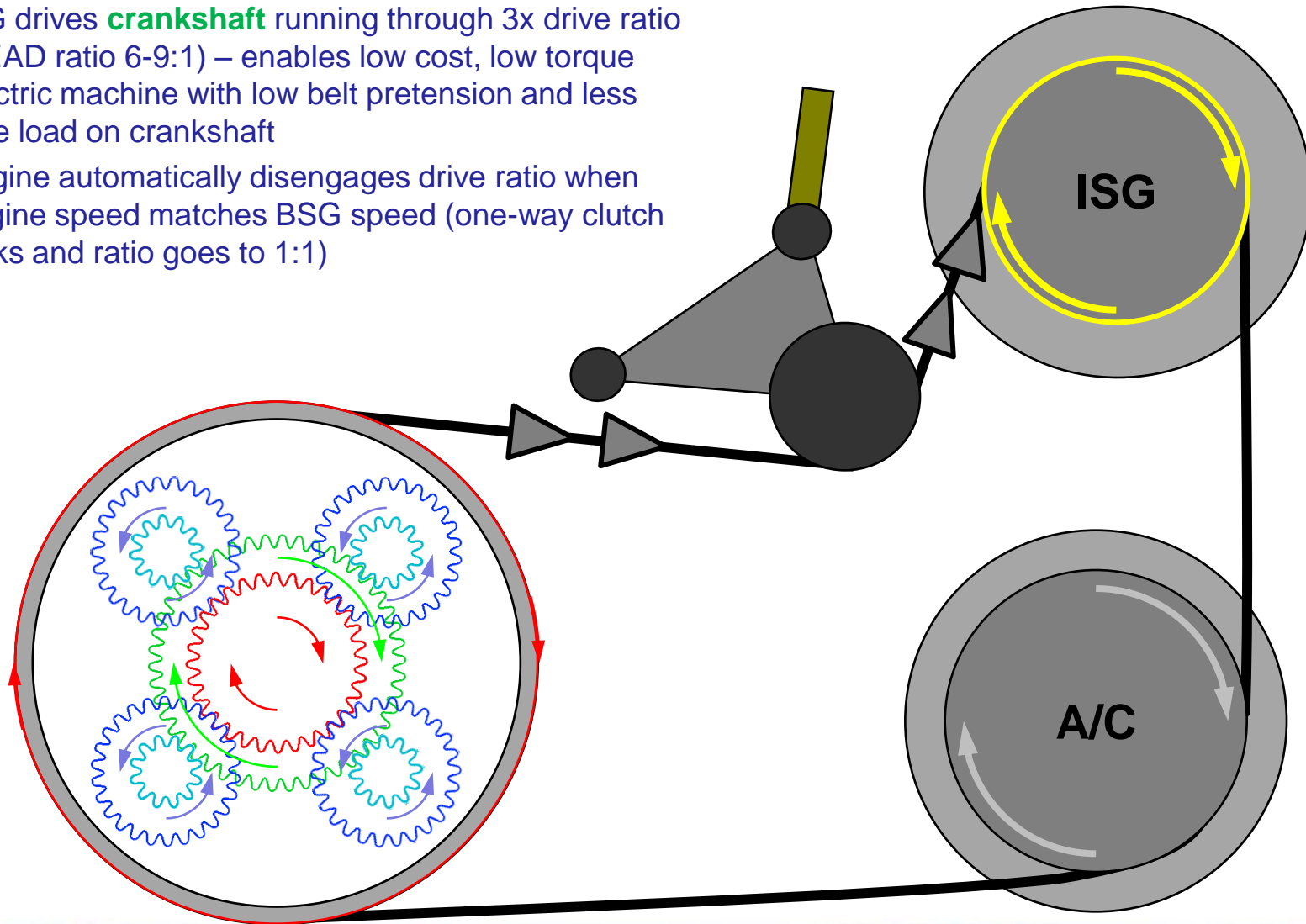
- Locking clutch disengaged – **crankshaft** drives **pulley** (no load on gearset)
- Opportunity to down-size and down-speed HVAC compressor and alternator as 3:1 drive mode can be used for HVAC pull-down and max-load battery recharge duty cycles
- Belt tension requirement reduced by larger diameter pulleys



3:1 Engine Restart Mode

High-Torque 3:1 Cranking Mode

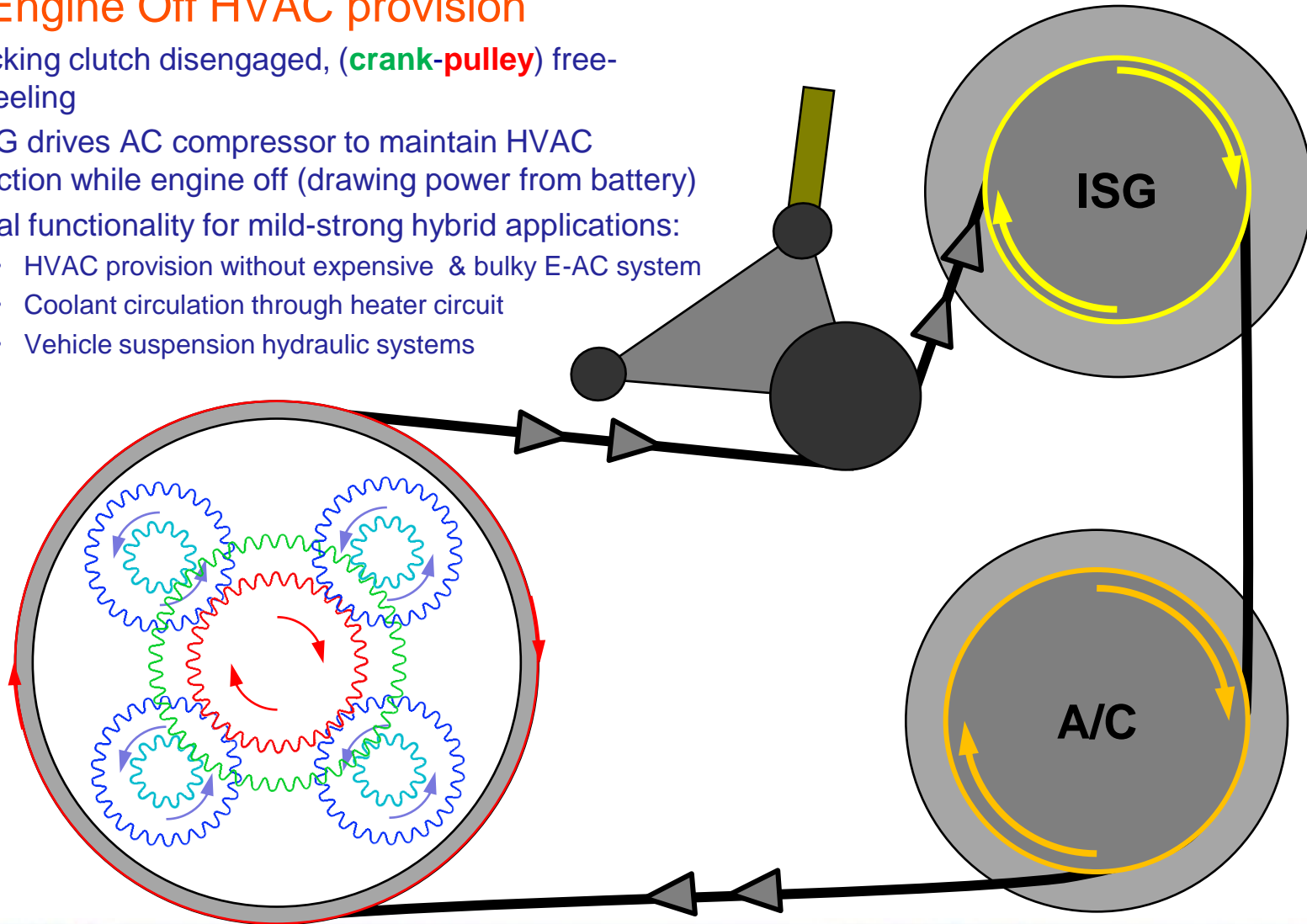
- ISG drives **crankshaft** running through 3x drive ratio (FEAD ratio 6-9:1) – enables low cost, low torque electric machine with low belt pretension and less side load on crankshaft
- Engine automatically disengages drive ratio when engine speed matches BSG speed (one-way clutch locks and ratio goes to 1:1)



1:0 Electric Ancillary Drive Mode

Electric drive of Ancillaries via B-ISG for Engine Off HVAC provision

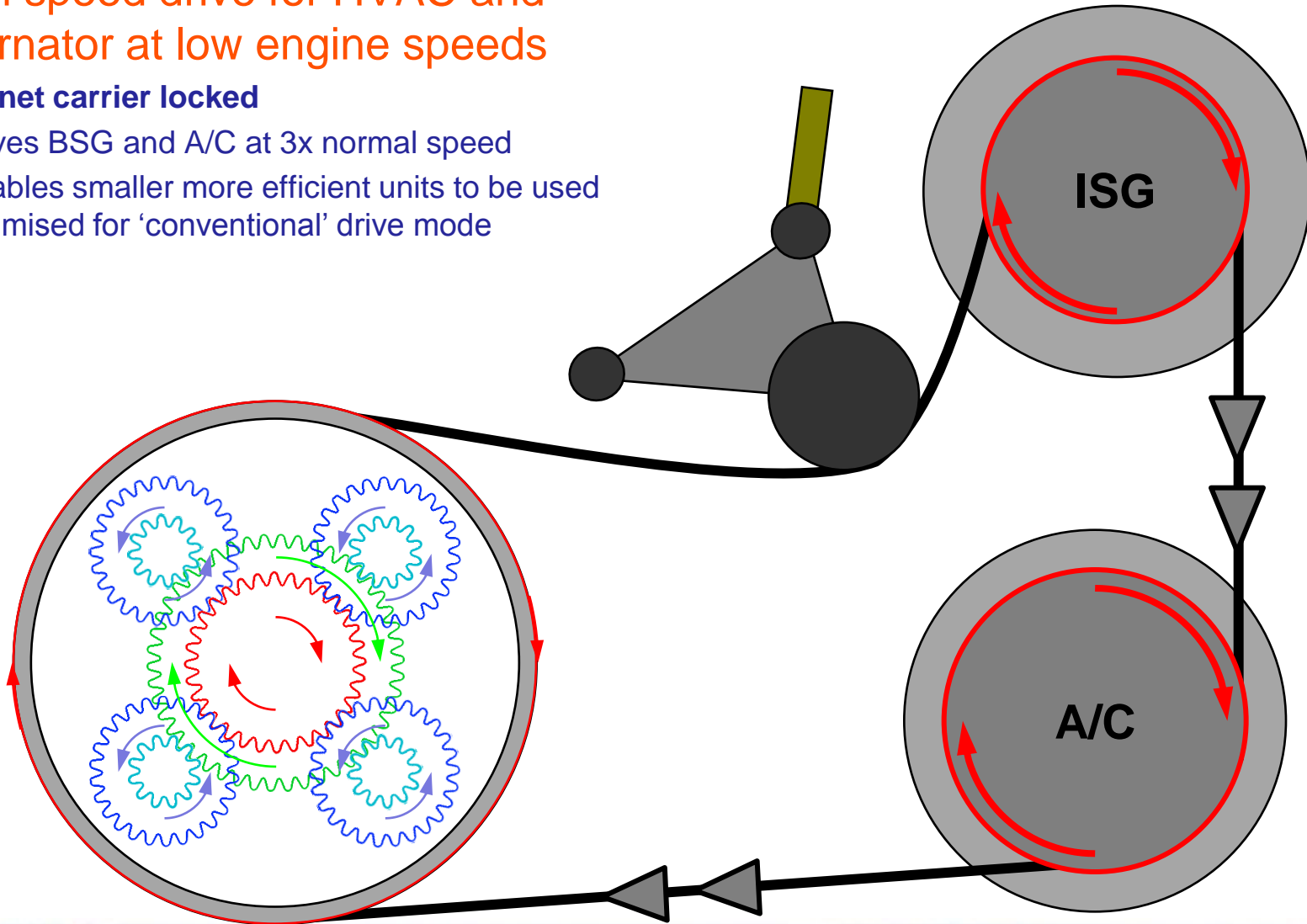
- Locking clutch disengaged, (**crank-pulley**) free-wheeling
- BSG drives AC compressor to maintain HVAC function while engine off (drawing power from battery)
- Ideal functionality for mild-strong hybrid applications:
 - HVAC provision without expensive & bulky E-AC system
 - Coolant circulation through heater circuit
 - Vehicle suspension hydraulic systems



3:1 Hi-Load Drive Mode

High speed drive for HVAC and Alternator at low engine speeds

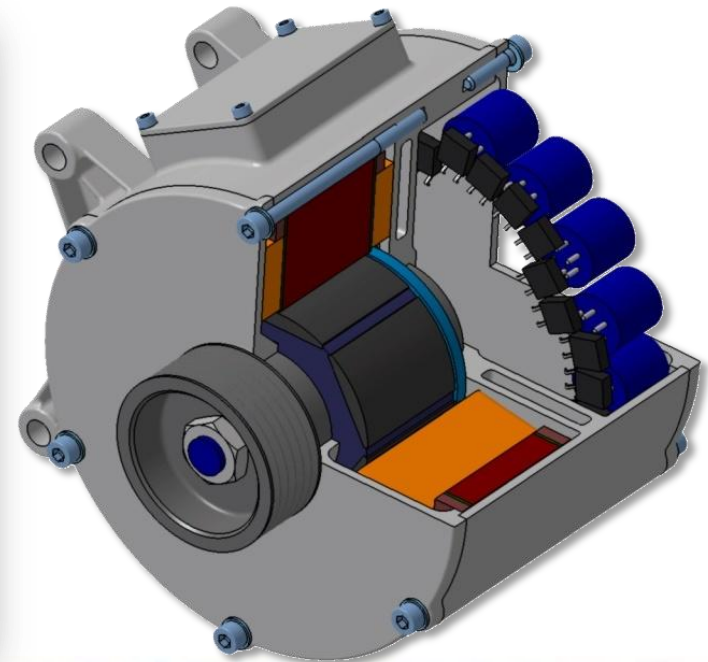
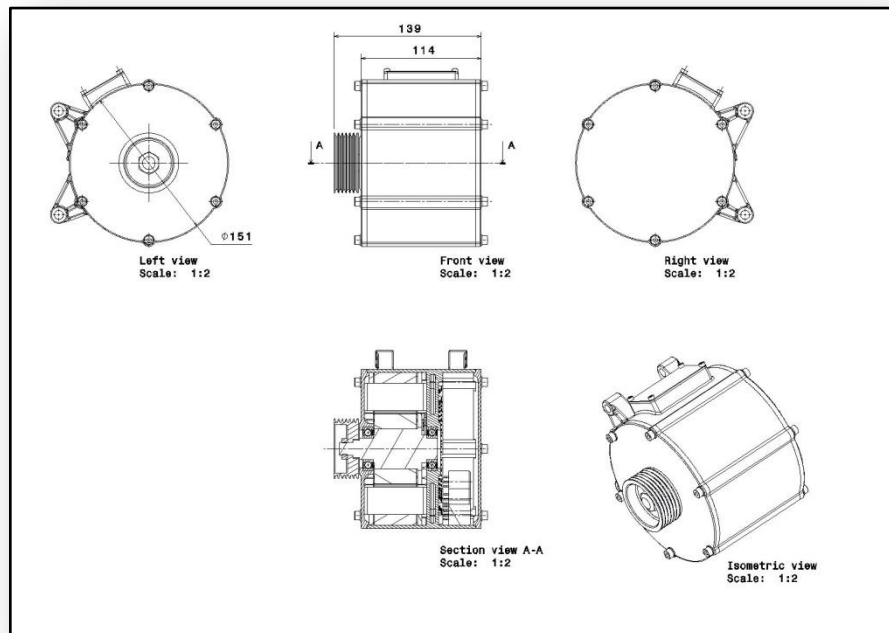
- Planet carrier locked
- Drives BSG and A/C at 3x normal speed
- Enables smaller more efficient units to be used optimised for 'conventional' drive mode



IP HS-ISG Electric Machine

Maximises benefits of VR-Pulley system

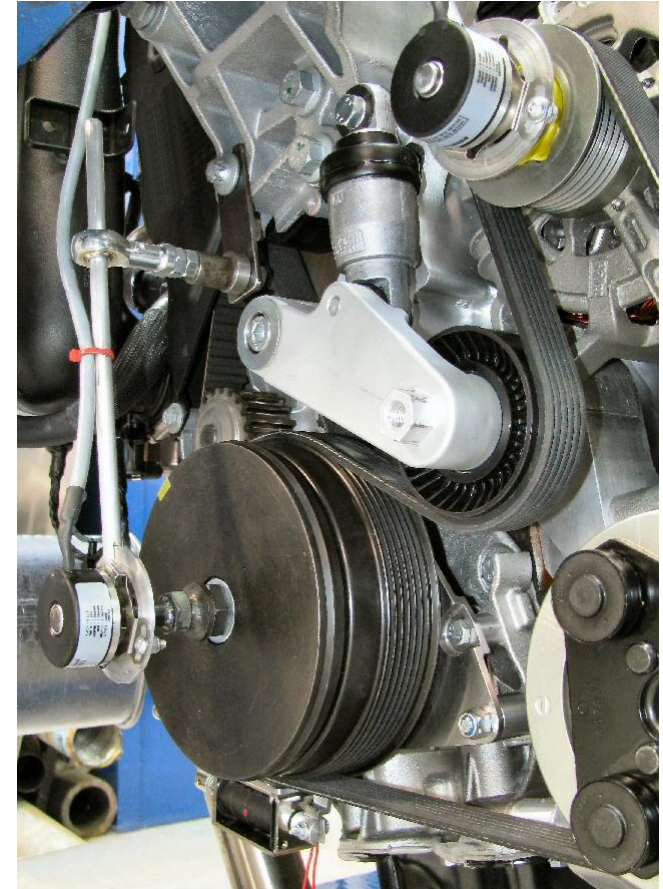
- High-speed ISG unit: Low-cost / low-torque design, 150D x 139L (incl. pulley)
- Low torque <25Nm, high power, ~6kW ReGen power, low mass <6kg
- IPM motor with low-cost integrated MOSFET based inverter and controller
- Bi-voltage 14/42~150V vehicle net
- Low-cost MOSFET based bi-directional DC-DC converter for 14V net
- Significant improvement in vehicle ReGen capability and total recovered energy
- Overall **much lower cost and mass** than conventional ISG systems



Programme Update – Q2 2009

Proof of Concept Hardware Demonstrated

- Proof-of-concept hardware designed and built.
- System has been demonstrated successfully on a I-4 diesel engine (> 2.0l capacity)
- Smooth & rapid 3:1 ratio engine cranking demonstrated at 20°C and fully warm with a 22Nm e-machine
- Engine-stop electric ancillary drive function tested
- Passive 1:1 engine ancillary drive tested

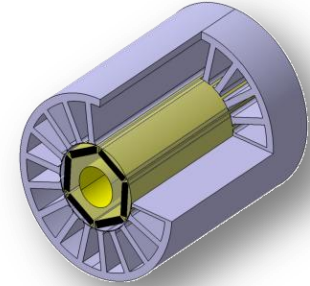


Hardware prototype for 2.0L Diesel hybrid application

System Scaleability

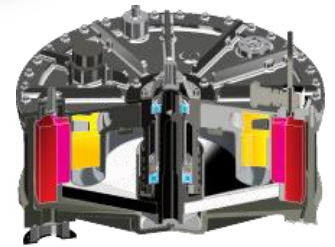
VR Micro-hybrid

- VR-Pulley plus high speed IPM e-machine
- Functions inc. stop-start, engine-stop ancillary drive, 6kW regen braking



i.hybrid

- Transmission integrated high speed motor
- Automated manual transmission
- VR-Pulley system with HS-BSG
- Williams hybrid-power EM-Flywheel KERS unit
- Hybrid functions incl. stop-start, engine-stop ancillary drive, torque assist, e-cruise and high power regenerative braking



pi.hybrid

- Adds additional battery packs to improve e-functionality
- ~Up to 6kW.hrs NiMh (150kg) or 6.0kW.hr AGM (240kg)
- Range, in e-mode up to 100km – 15km / kw.hr of NiMH

