EVS32 A world of E MOTION
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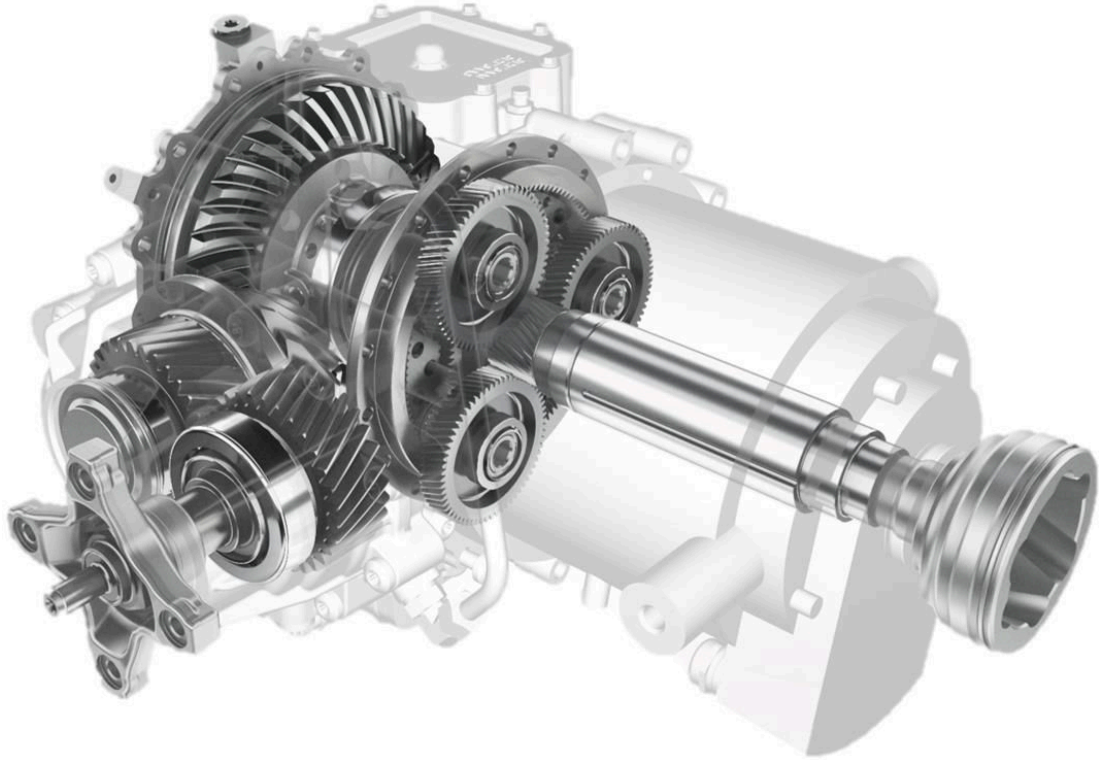
INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION
EVS 50th anniversary 1969-2019

H-RAM : hybrid rear axle module

An innovative hybrid differential for P3 and P4 applications

Sergio De Santis, Dana Incorporated, Italy



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Overview of H-RAM concept

Benefits of highly integrated design

Performance and control of P3 H-RAM

Modularity advantages for P3 and P4 applications

Project status

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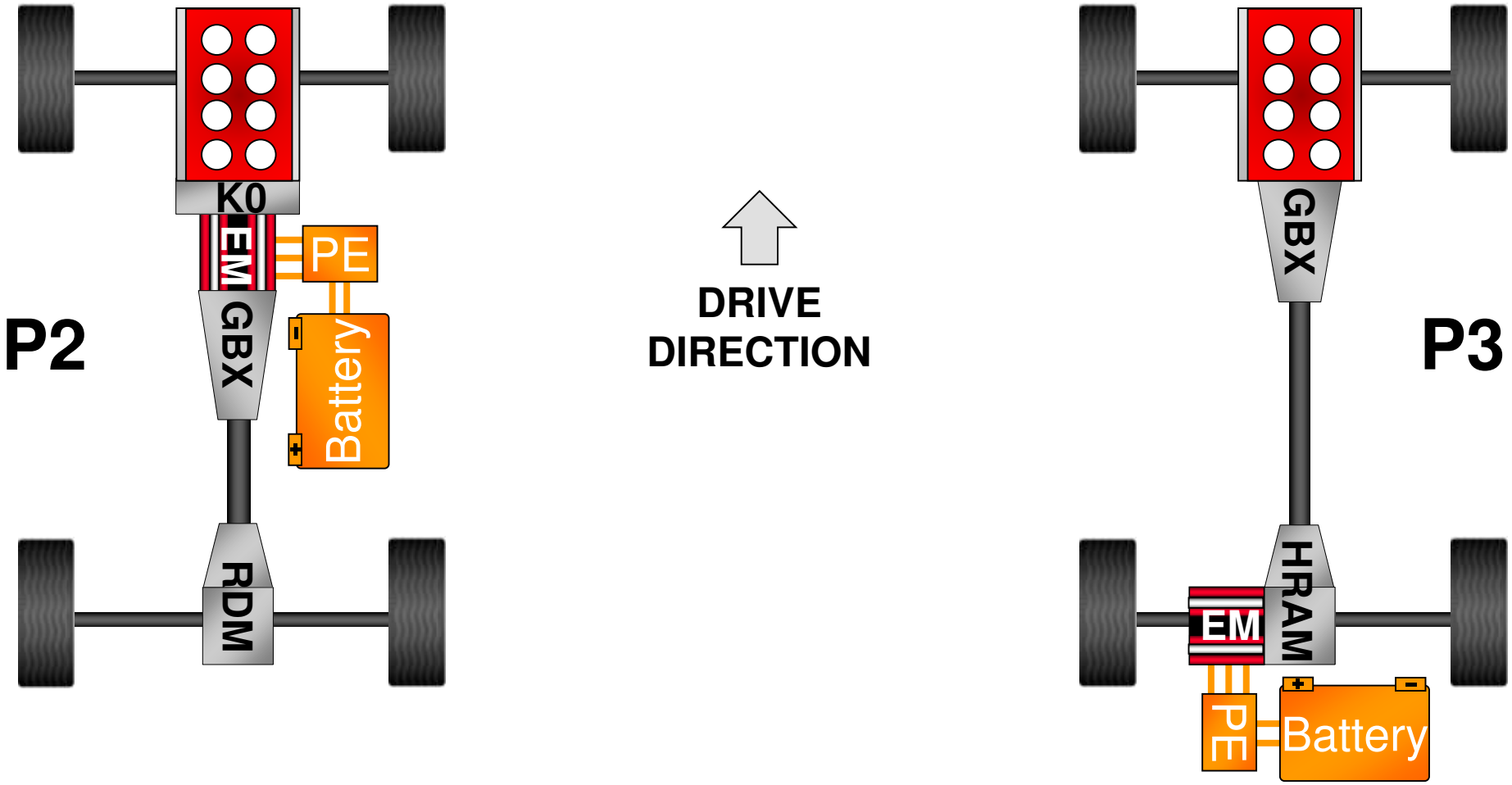
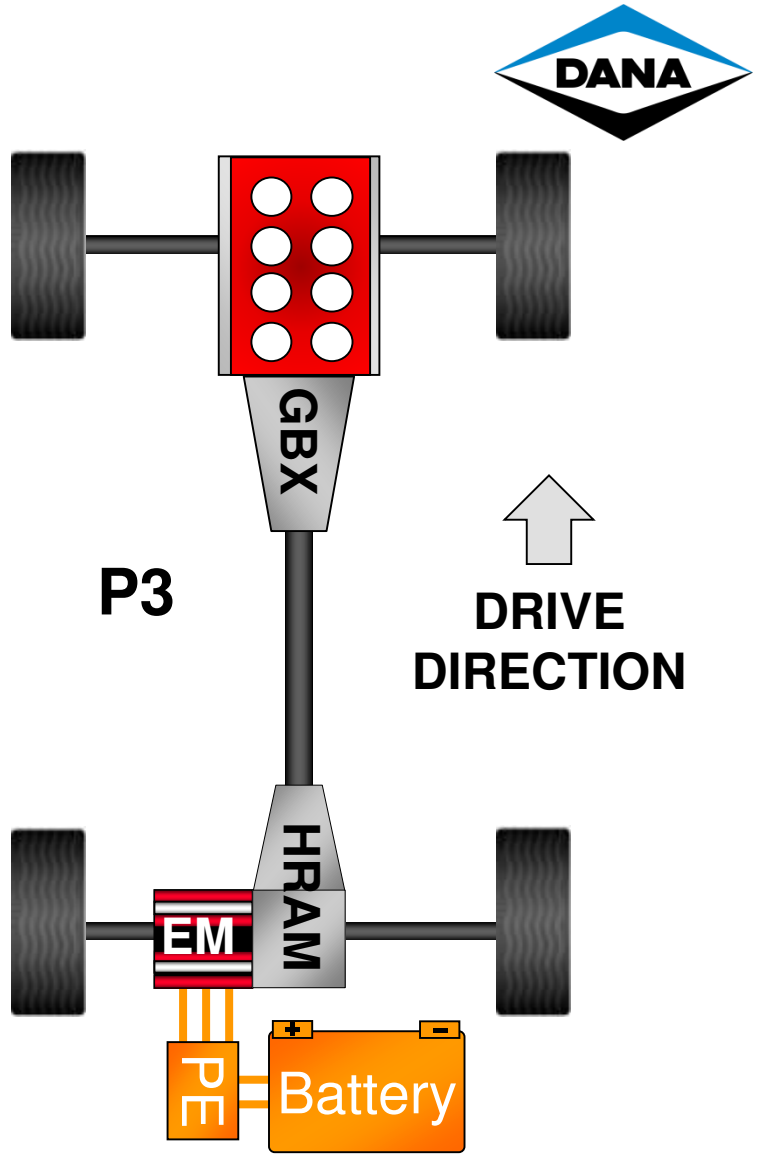
Advantages of P3 Vs P2



Overview of H-RAM concept

Advantages of P3 Vs P2

- No modifications needed on the ICE and gearbox
- Less torque through gearbox
- P3 offer better efficiency in particular in EV mode
  - Energy consumption reduced by 8 % during WLTP
- Battery Boost characteristics



Overview of H-RAM concept

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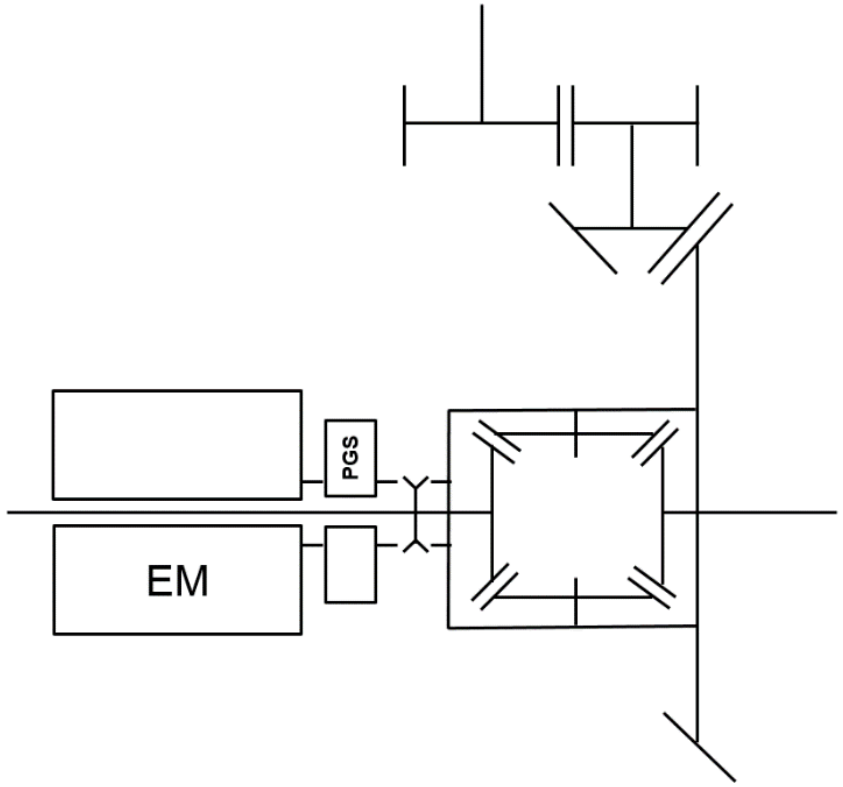
P3 Hybrid / P4 module

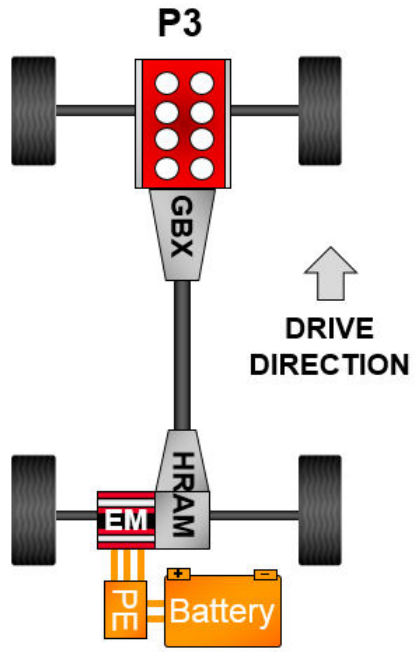
Functionalities

- Full electric drive
- Acceleration ICE only
- Acceleration ICE and E-Motor
- Recuperation during braking

Key features:

- 2 Speed between EM and wheels.
- EM coaxial to half shafts
- eLSD (Electronic limited slip differential)





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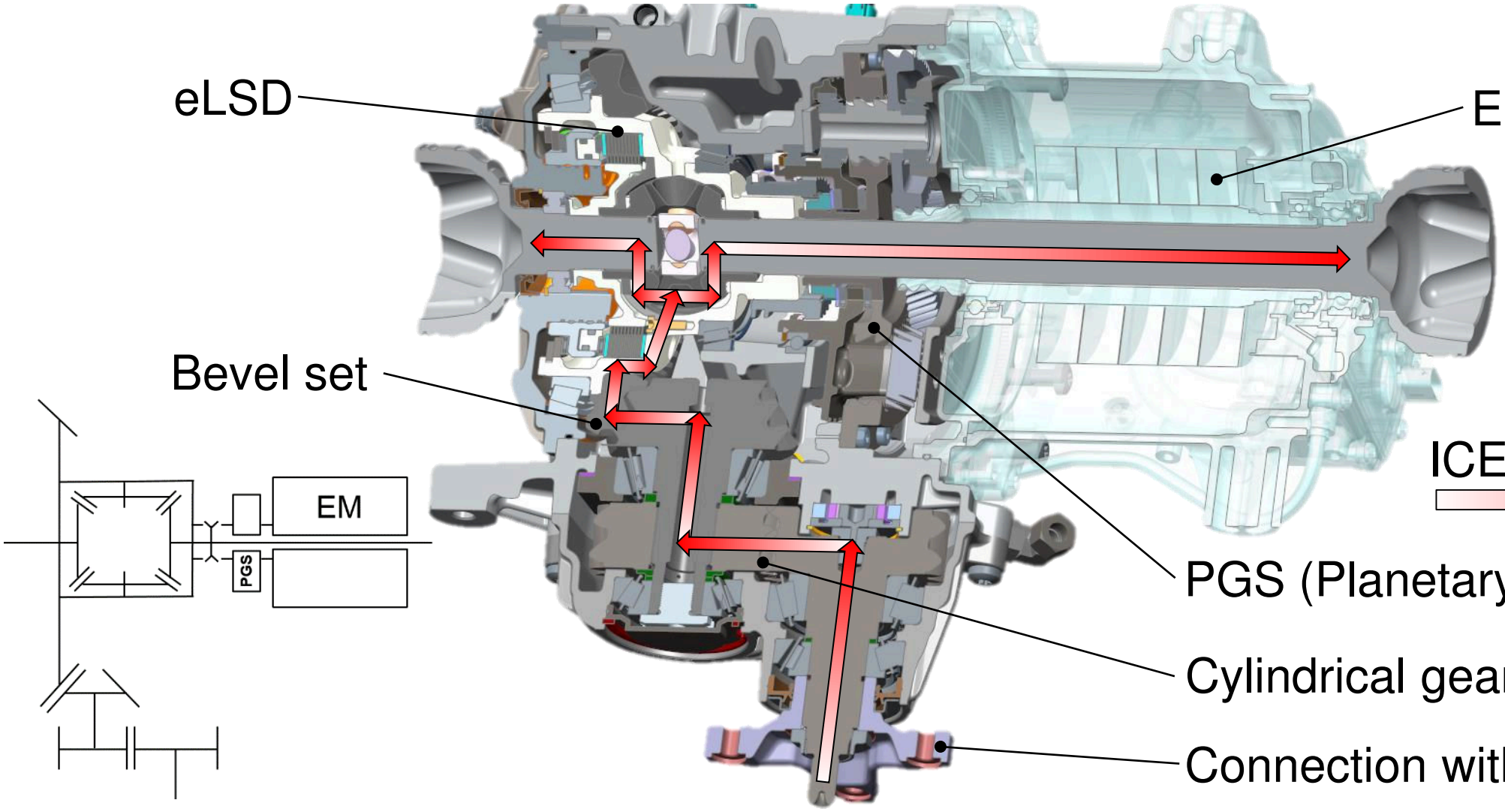

Overview of H-RAM concept

2 speed actuation – 1st speed

E-TORQUE PATH

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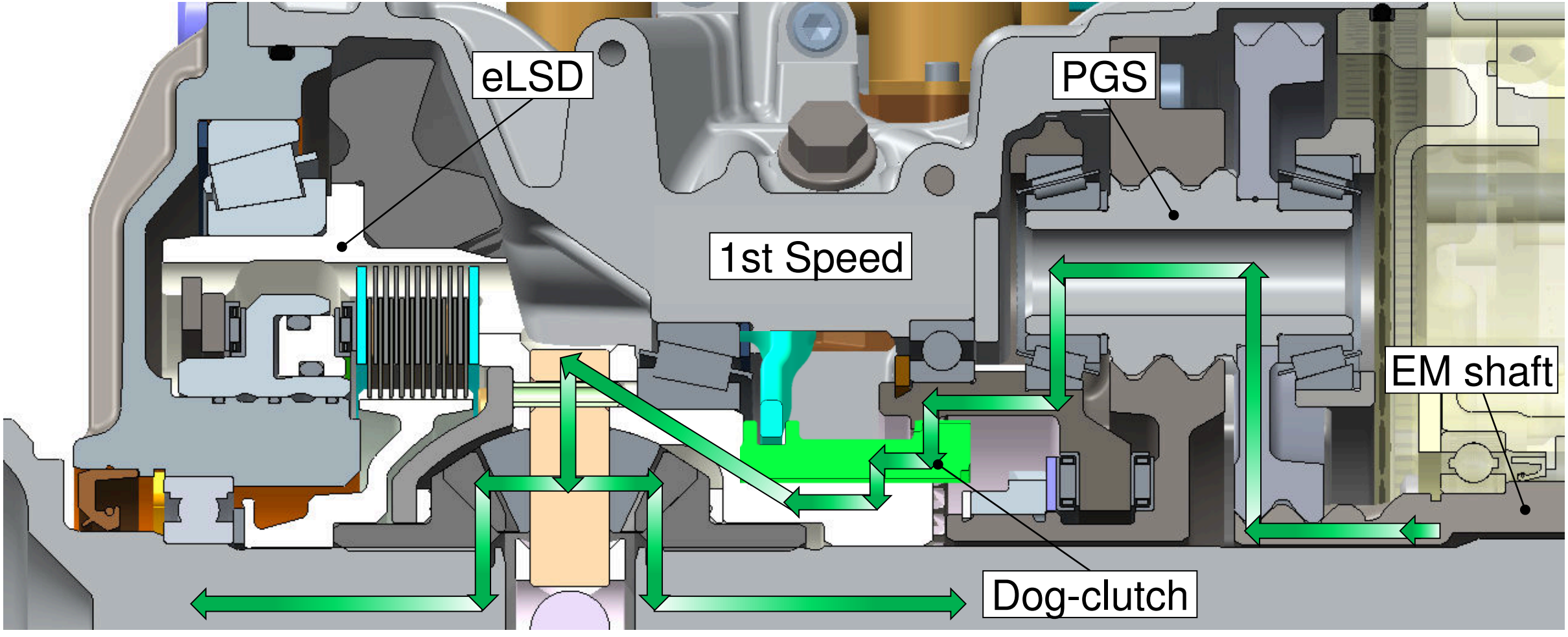

Overview of H-RAM concept

2 speed actuation – 2nd speed

E-TORQUE PATH

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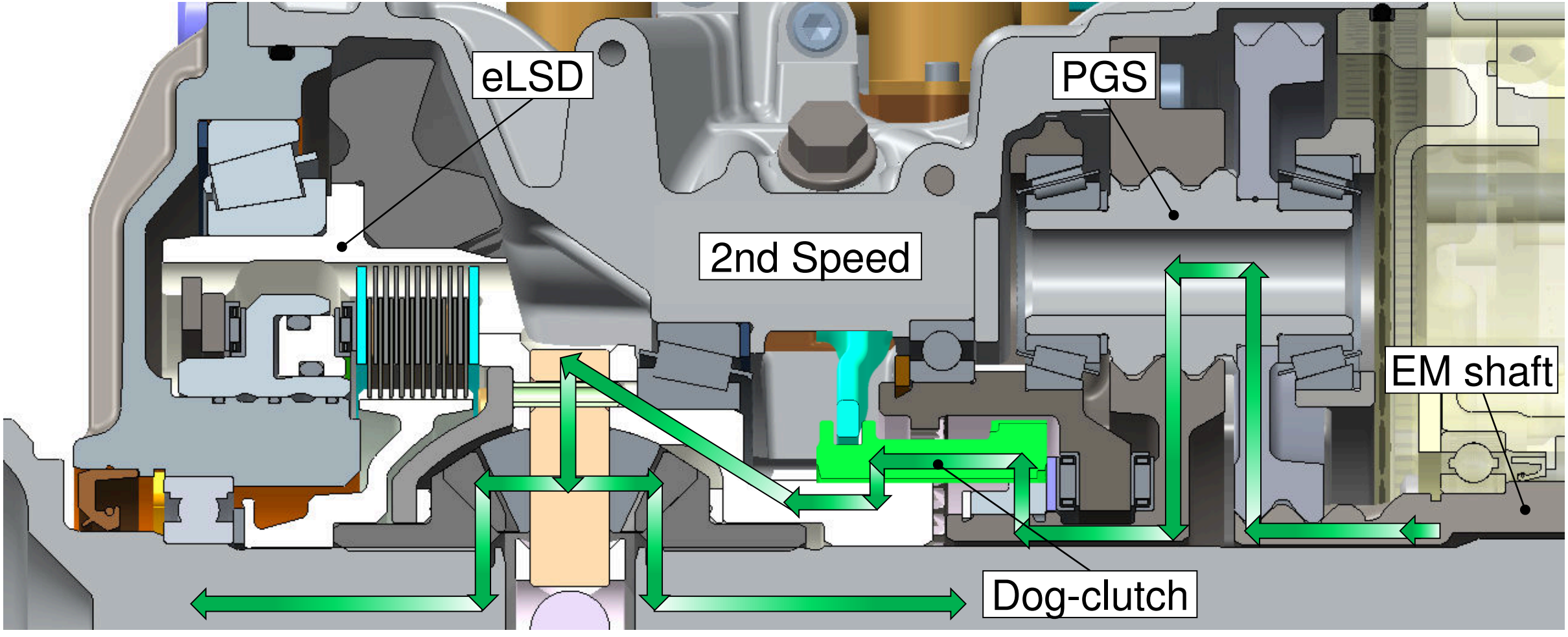
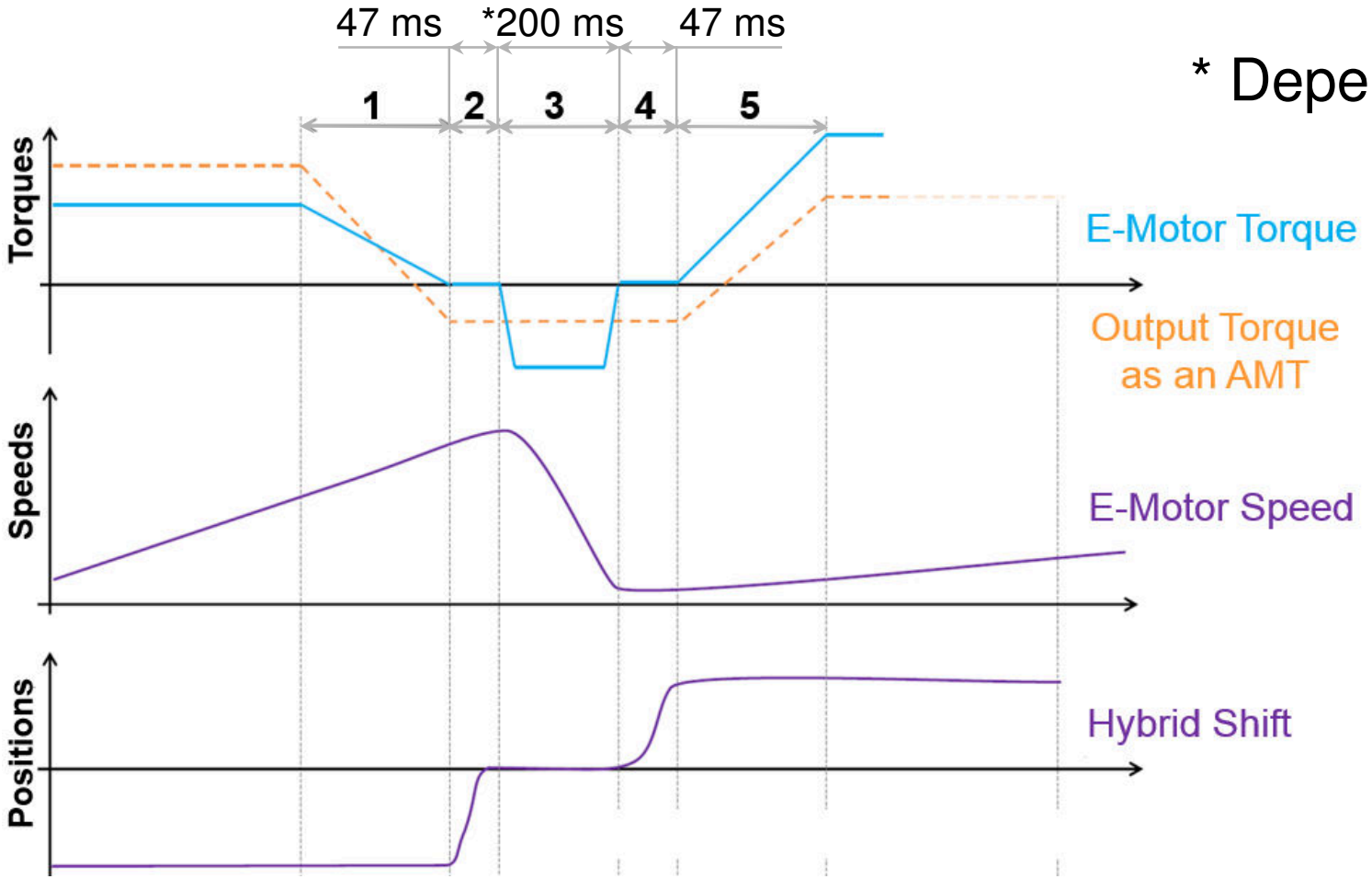


Overview of H-RAM concept

Shifting example from 1st to 2nd speed



* Depending on HV system specification

1. **Torque reduction**
2. **Neutral selection**
3. **Speed synchronisation to new gear**
4. **Gear selection**
5. **Torque increase**

Overview of H-RAM concept

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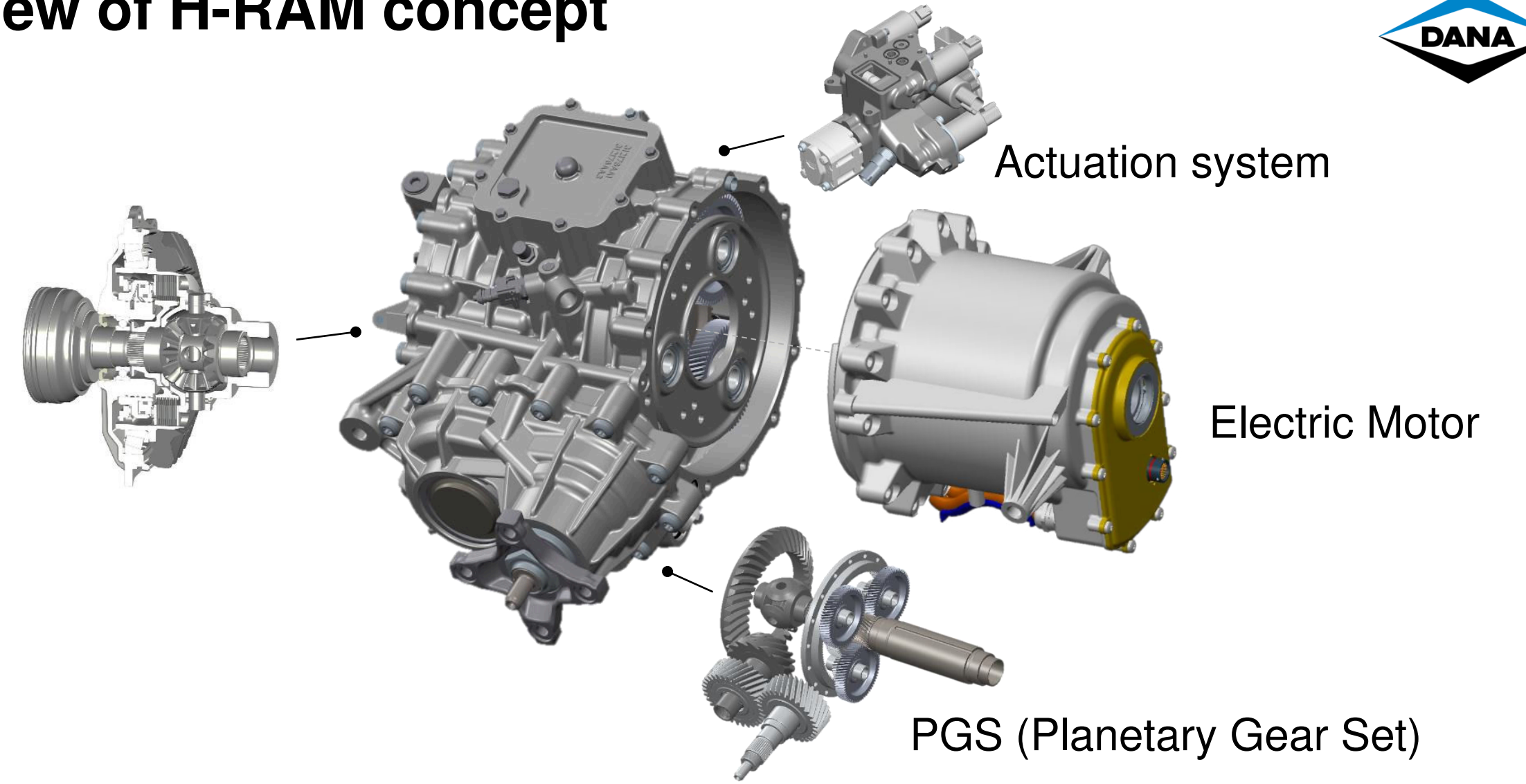

Overview of H-RAM concept
Actuation system

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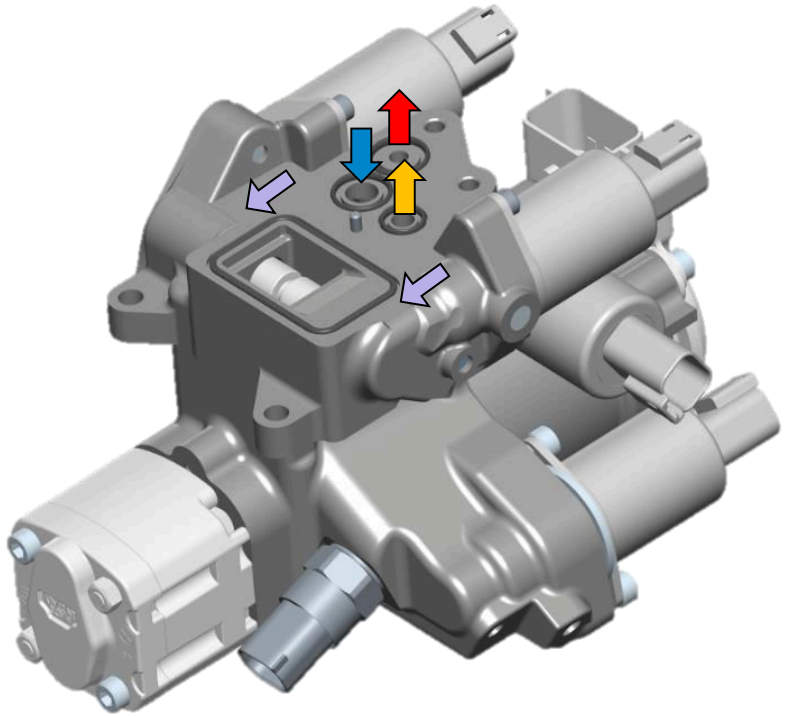
- Single hydraulic actuator controlling eLSD and shifting system
- No accumulator
- Light weight: 3.8 kg
- No external hydraulic pipes



Overview of H-RAM concept

PGS (Planetary Gear Set)

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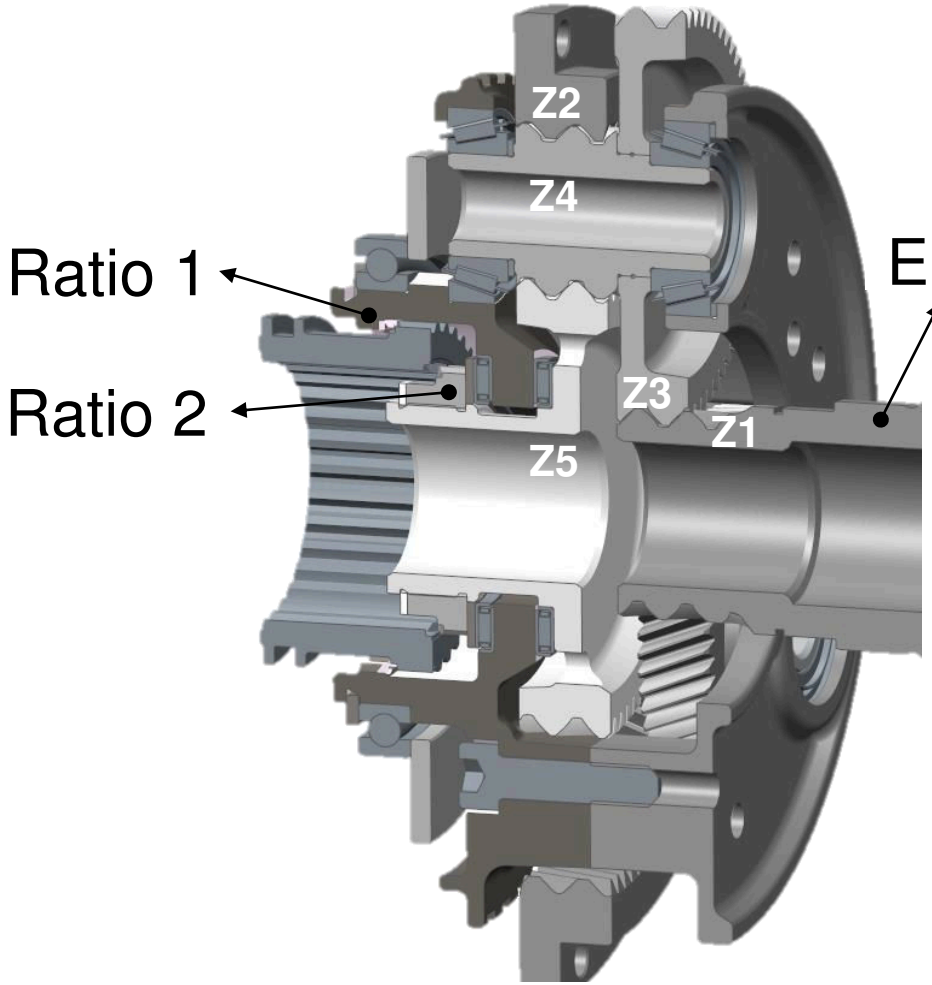
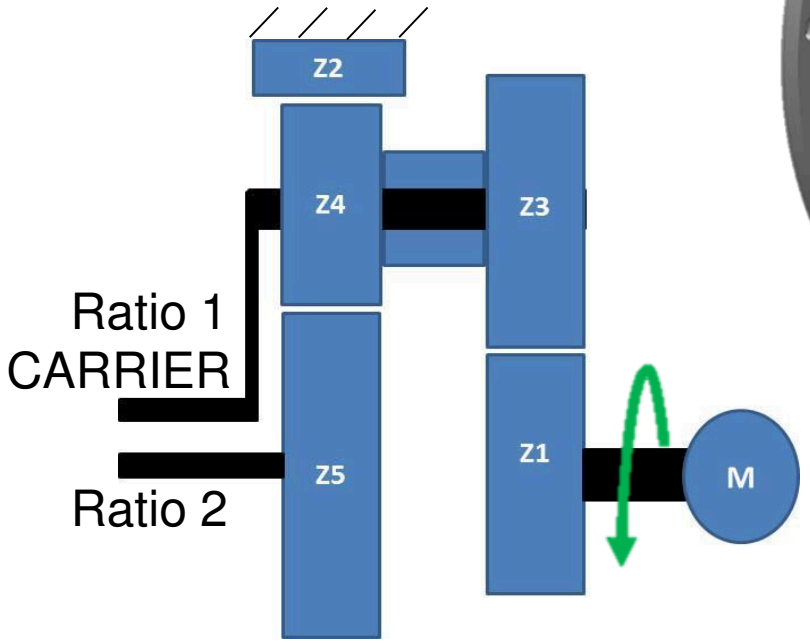


$i_{1st} = 11,9$

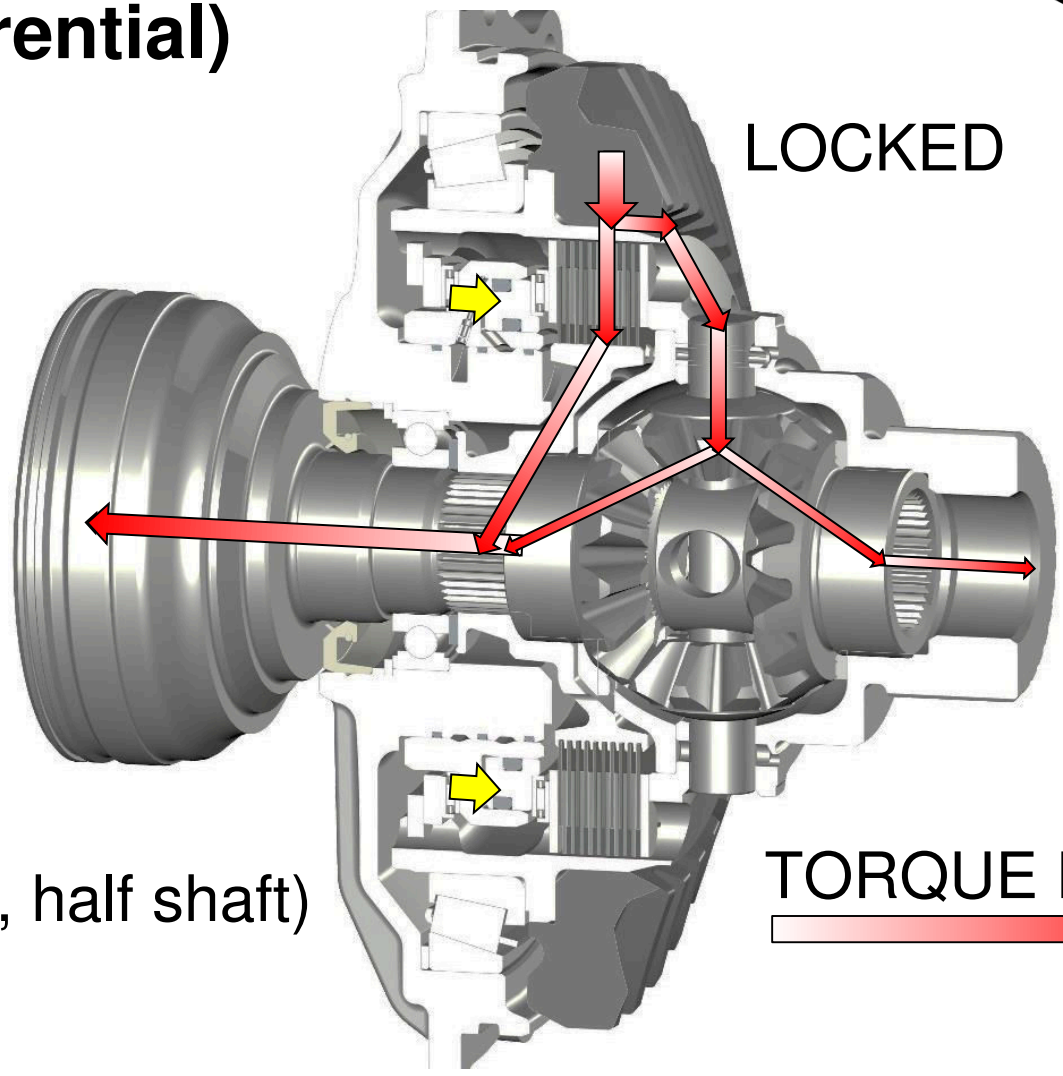
$i_{2nd} = 4,58$



Overview of H-RAM concept

eLSD (Electronic Limited Slip Differential)

- Max output torque approx. 12000Nm
- Max locking torque up to 2500Nm
- Actuation time:
  - Step-up response 70ms
  - Step-down response 70ms
- Weight: 9.5 Kg (w/o : bevel gear, cover, half shaft)



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- Overview of H-RAM concept
- Benefits of highly integrated design
- Performance and control of P3 H-RAM
- Modularity advantages for P3 and P4 applications
- Project status

Benefits of highly integrated design

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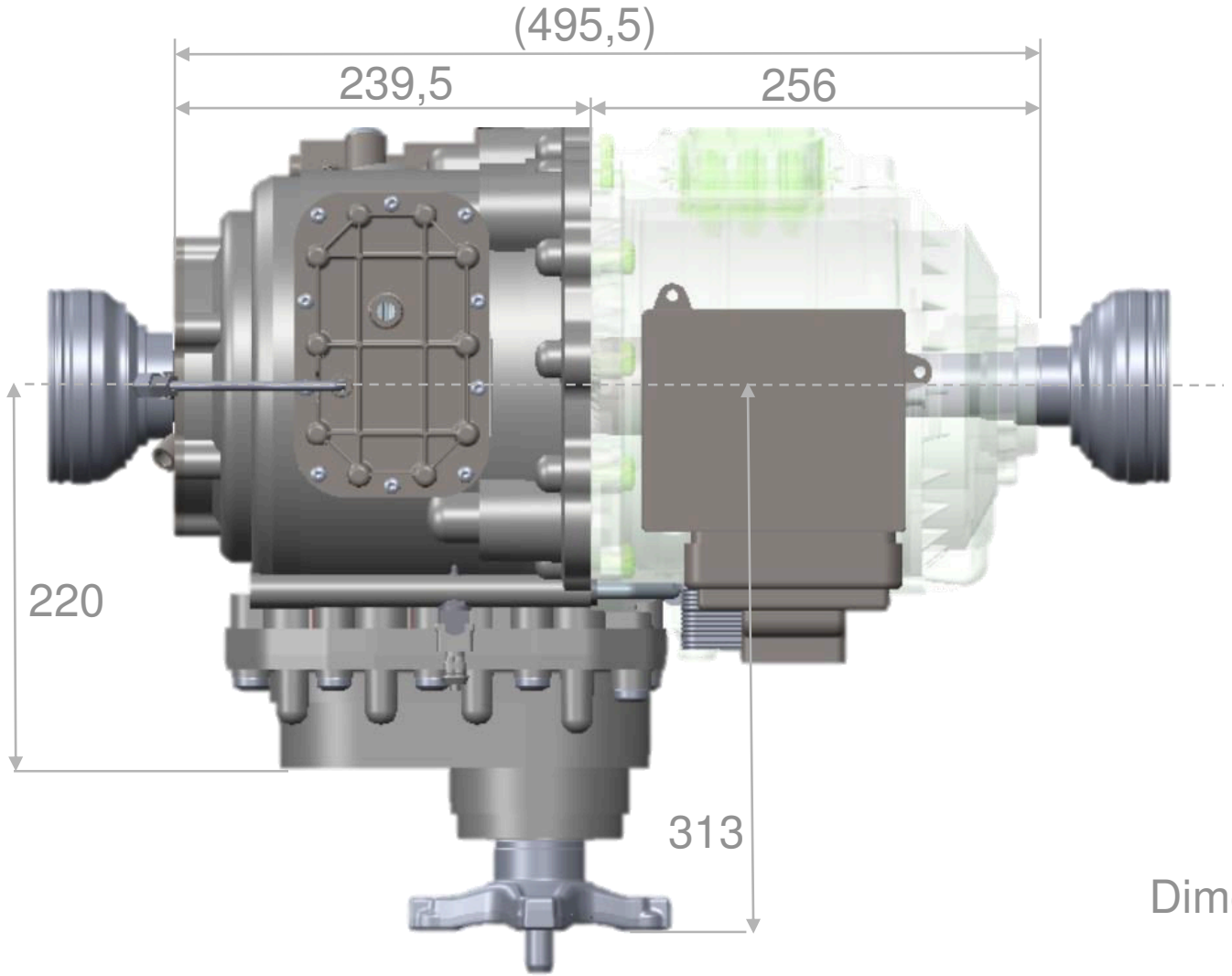

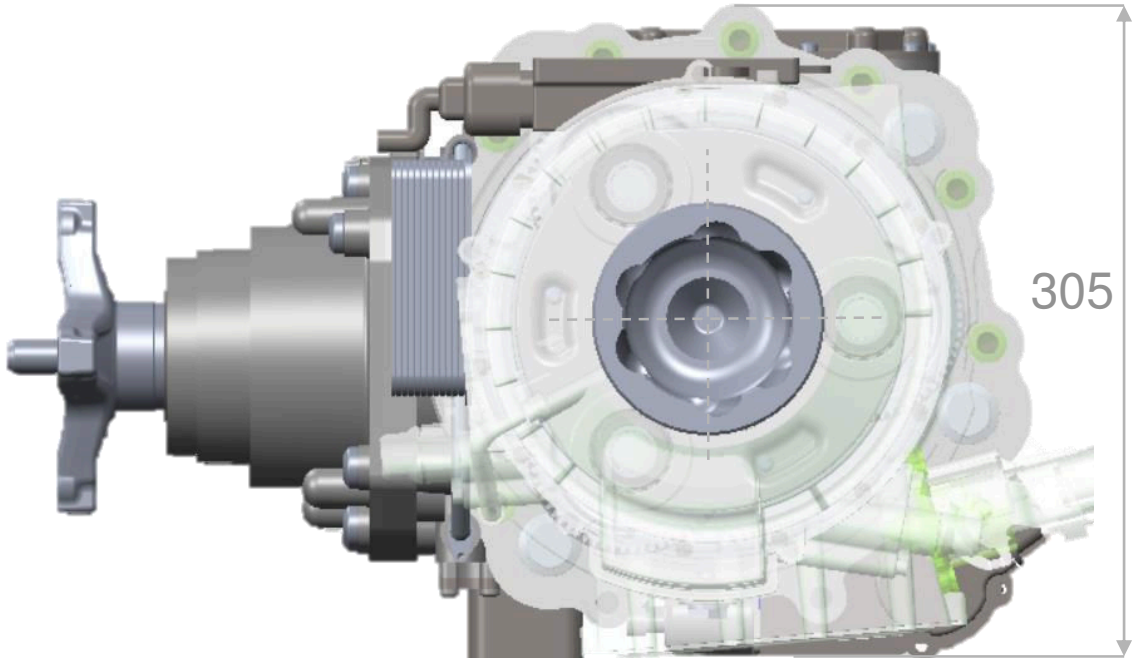

Dimensions in [mm]

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Performance and control of P3 H-RAM

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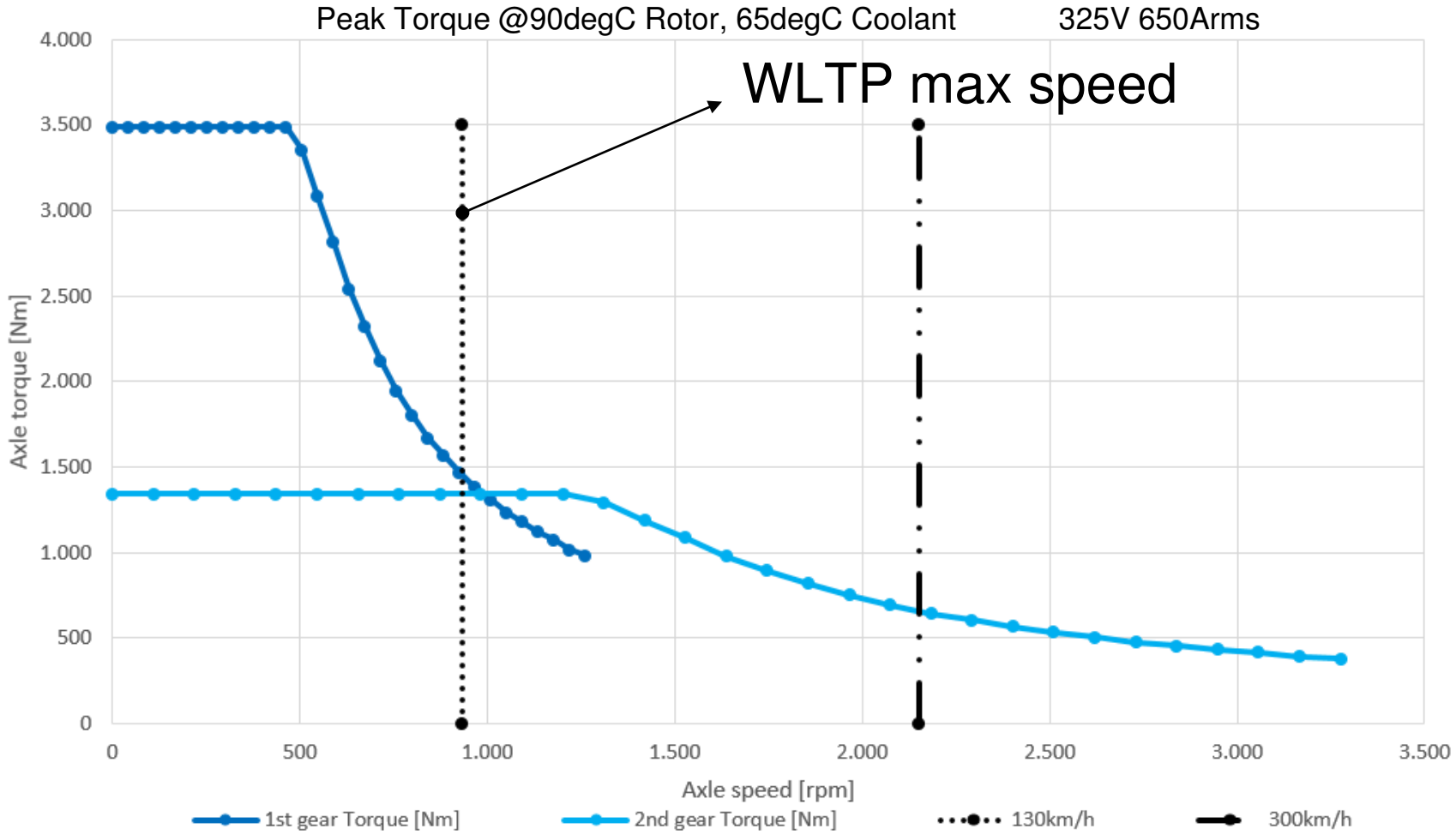
	Characteristics
E-mode ratios	Ratio 1 : 11,9 Ratio 2 : 4,58
Total final drive ratio	(2,44 ÷ 3,47) : 1
EM Torque (peak)	293 Nm
EM Power (peak)	176 kW
EM max speed	15000 rpm
Max torque in E-mode (@ wheel)	3500 Nm
Peak torque – hybrid mode (@ wheel)	12000 Nm
Max eLSD locking torque	Up to 2500 Nm
Max vehicle speed in e-mode	> 300 Km/h
Weight	92 Kg (included E-machine)

Performance and control of P3 H-RAM

Output torque and speed in e-mode

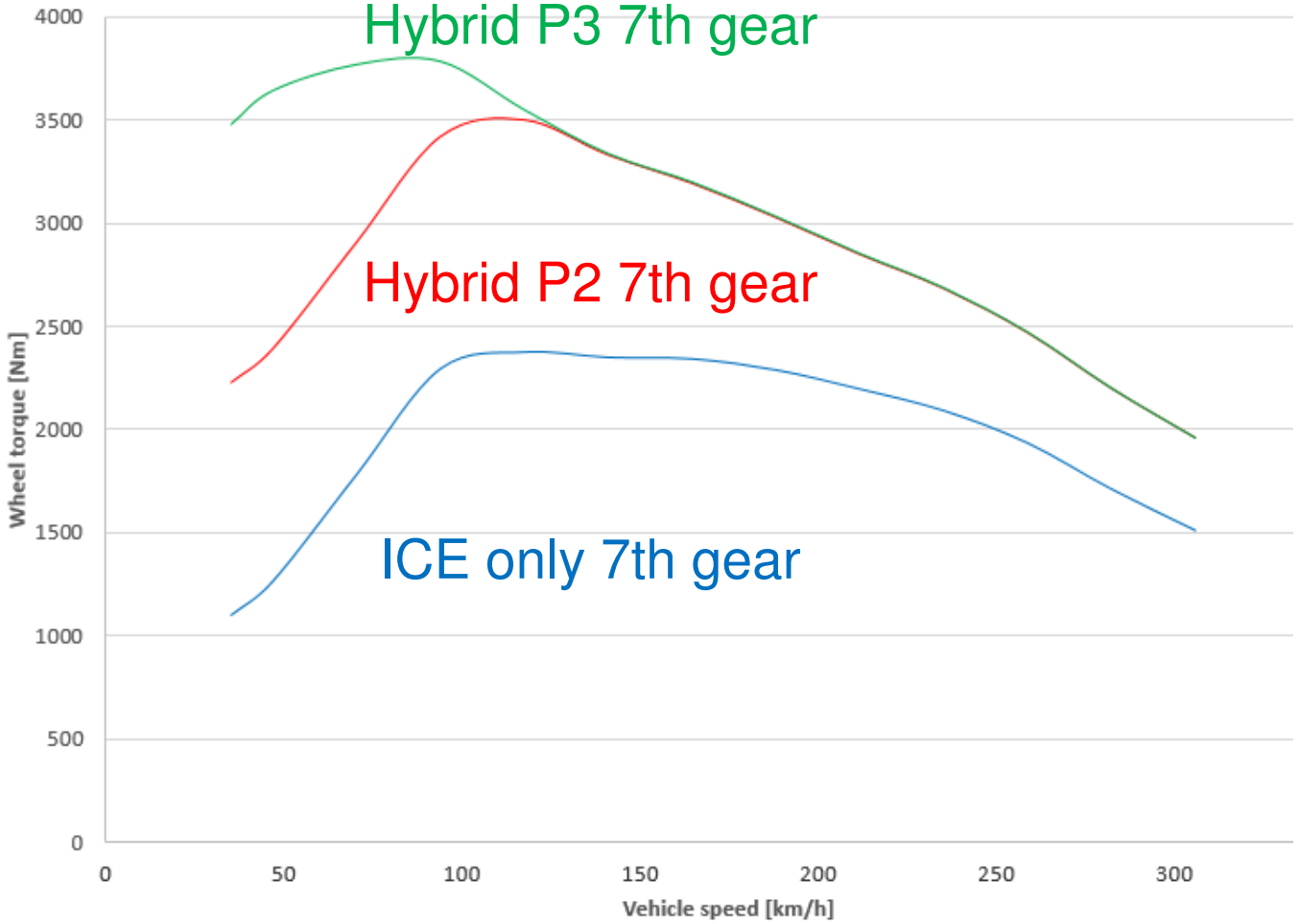
$i_{1st} = 11,9$

$i_{2nd} = 4,58$



Performance and control of P3 H-RAM

P2 Vs P3 Hybrid wheel torque



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Modularity advantages for P3 and P4 applications

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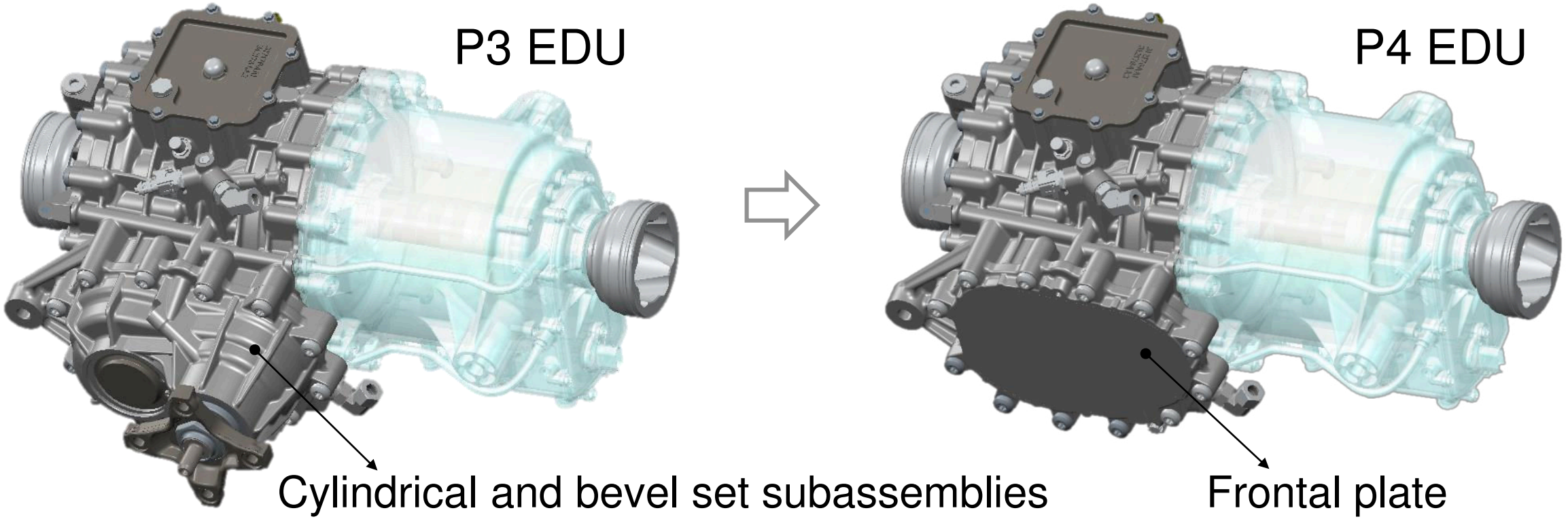

In the P4 layout the cylindrical and bevel set subassemblies will not be assembled, a frontal plate will replace it.

Modularity advantages for P3 and P4 applications

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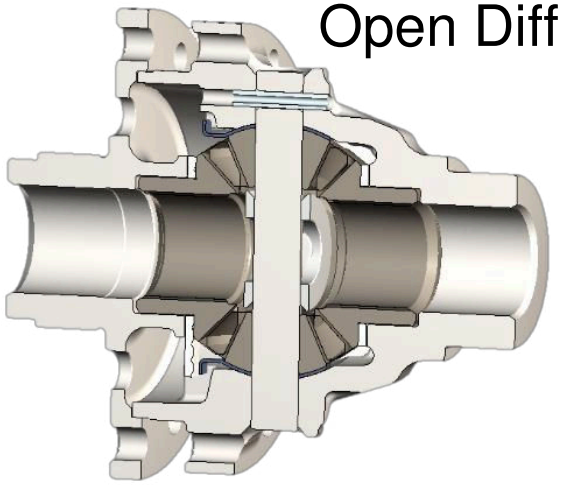
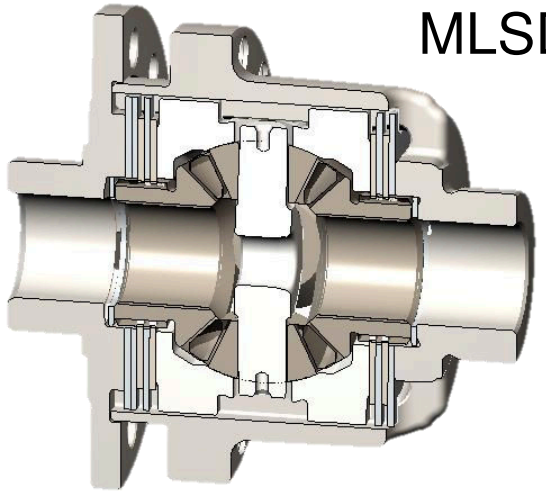
Differential options	FD ratio [Hybrid variant]	P4 variant
Open	2,44 ÷ 3,47	✓
MLSD	2,44 ÷ 3,47	✓
eLSD	2,44 ÷ 3,47	✓

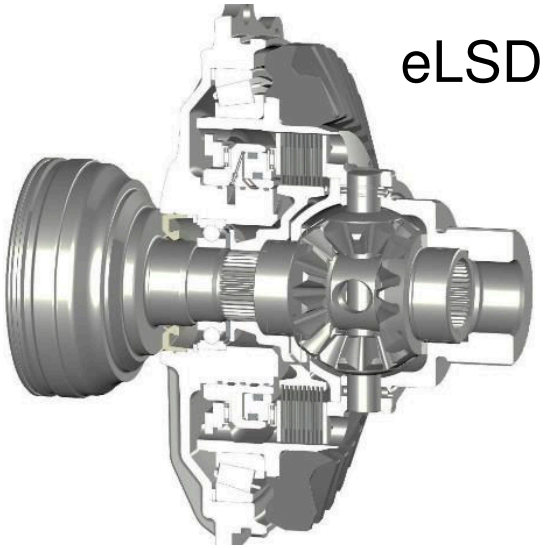
Open Diff



MLSD



eLSD



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- Prototypes realized ✓
- Concept validation on bench ✓
- Concept validation on vehicle (by customers) ✓
- B-sample design optimization ✓
- Suppliers sourcing for a B-phase ✓

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