

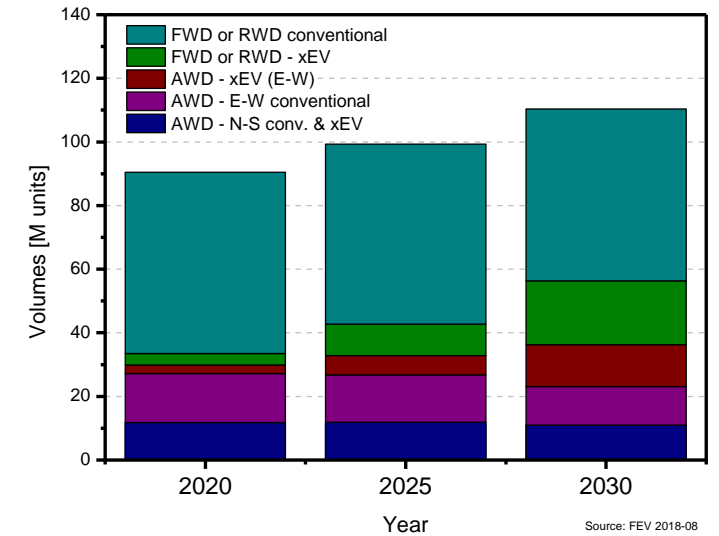
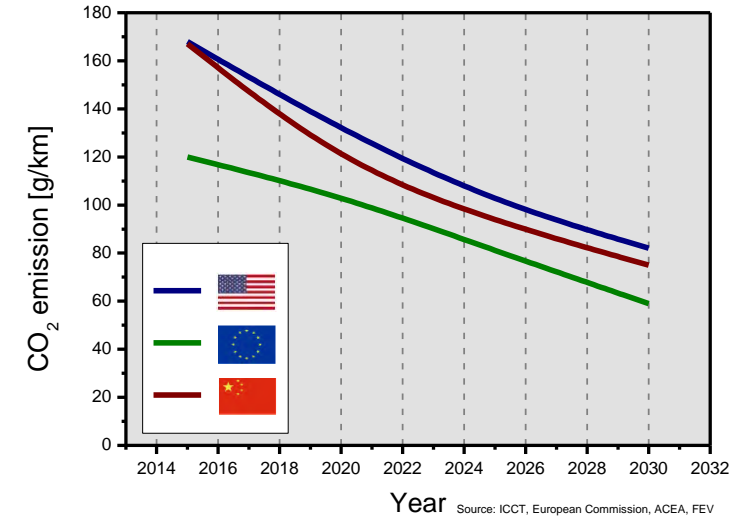
Twin AWD

A new approach on AWD hang on systems

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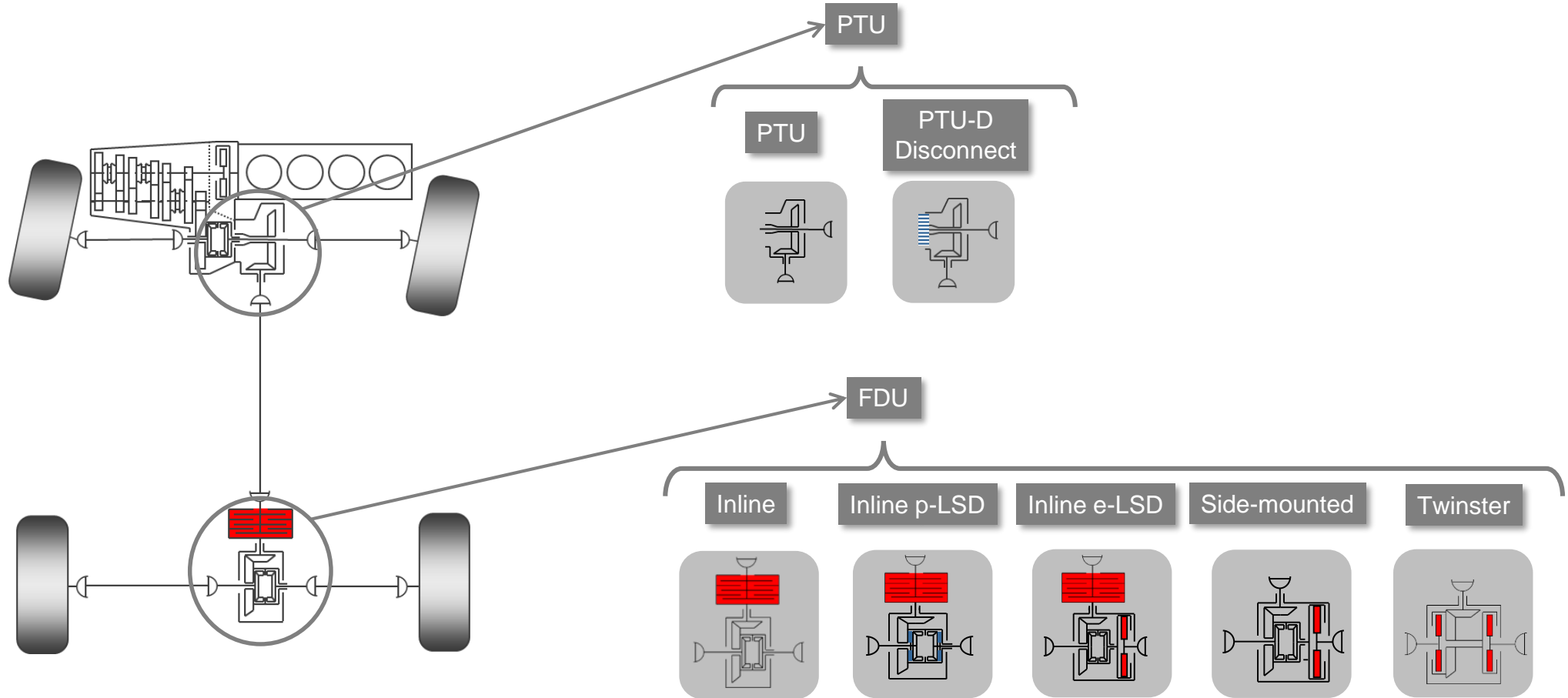
- > Challenges on AWD-Systems
- > Overview on East West AWD-Systems
- > AWD-Systems concept study
- > Vision
- > System Requirements and Performance
- > Summary

- > CO₂ legislation is driving efficiency demands (EU 2030: 67g/km)
- > Regional demands for AWD-Systems are very different (USA/EU/AP)
 - Drives complexity on driveline layout
 - Active Connect systems will increase where AWD share is high
 - AWD-System needs to be robust, flexible, easy adaptable and efficient
 - A global footprint is more than ever requested
 - Cost pressure will increase, to compensate for complexity
- > 2030 forecast shows still high AWD volume but...
 - Partly substituted by P4 e-axes
 - Mech. AWD systems market will shrink
 - Competition on mech. AWD will increase
 - Strategically important to re-use AWD mechatronic modules on e-axes
 - eLSD, Twinster, actuation



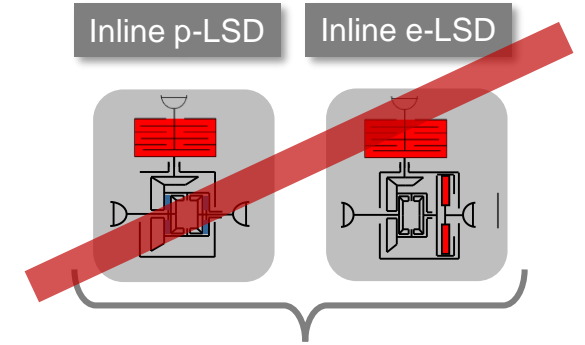
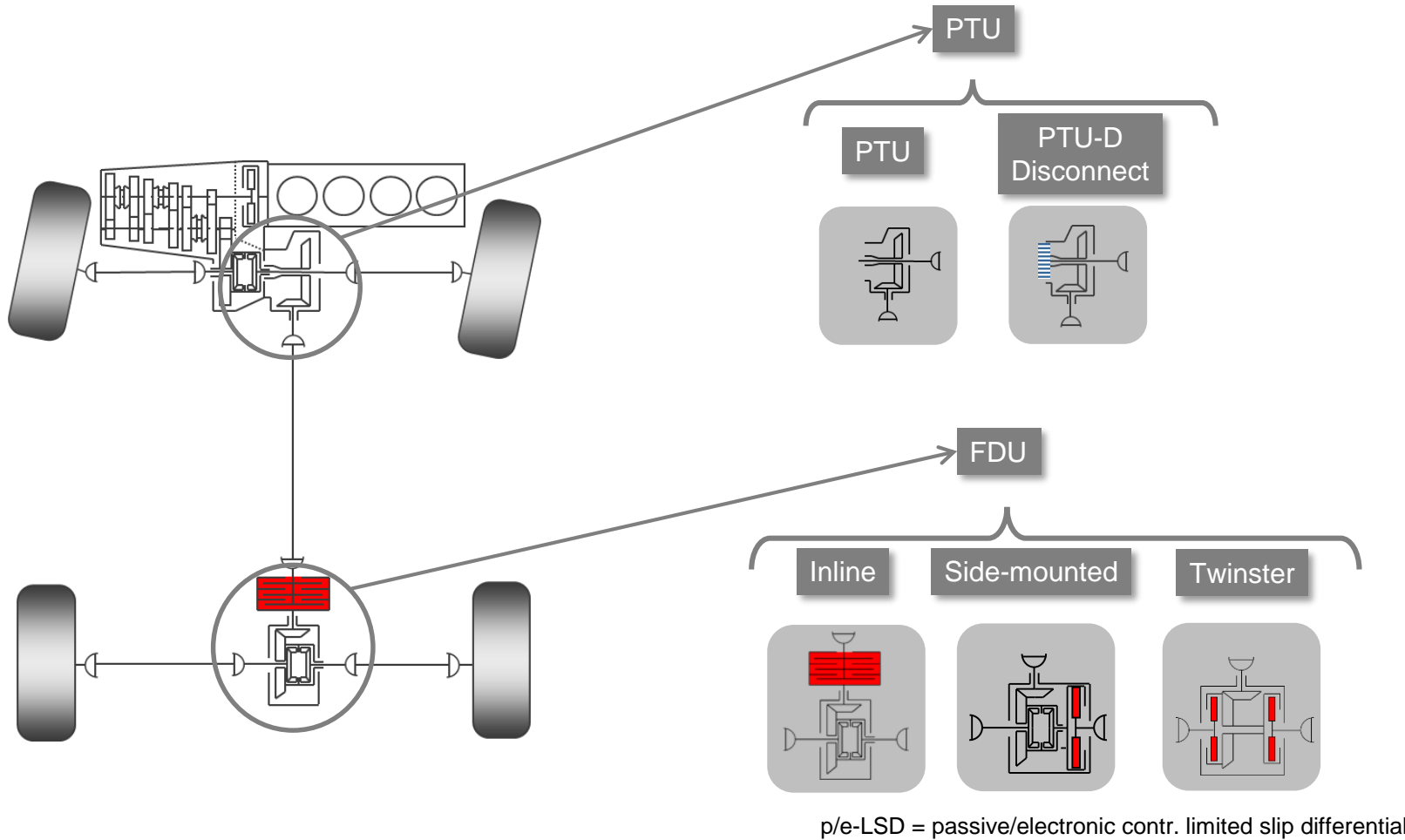
Overview on East-West AWD-Systems

Current East-West AWD hang on systems on the global market are already complex



p/e-LSD = passive/electronic contr. limited slip differential

Can we make it more simple? - GKN's Portfolio



Substituted by Twinstar because of:

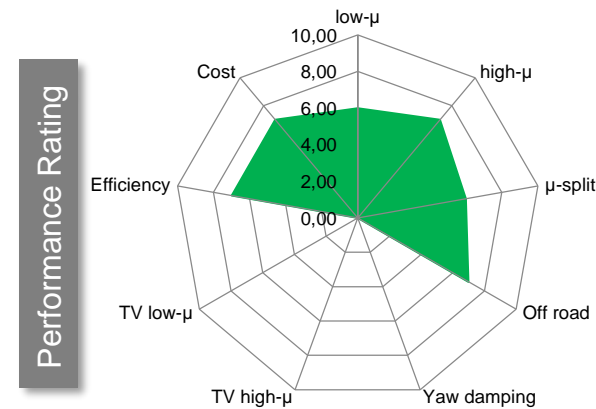
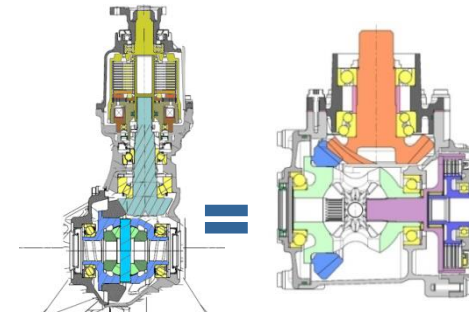
- > Reduced complexity
- > Lower cost
- > Improved performance
 - eLSD (for p-LSD only)
 - Torque Vectoring
 - Active Connect compatible

AWD-Systems concept study

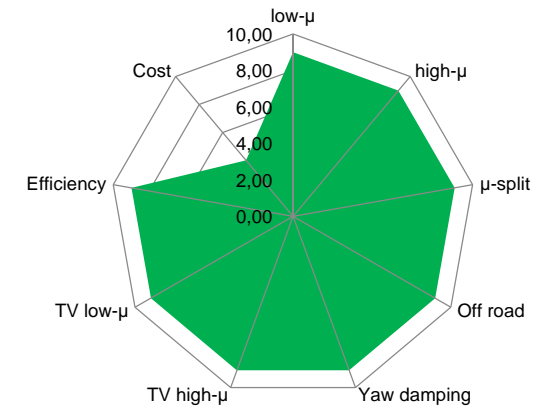
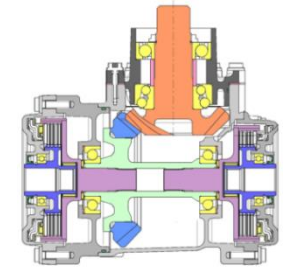
State of the art AWD hang on Systems:

- > Inline coupling bolted on a rear axle housing
- > Side mounted coupling
 - 1 Coupling integrated into RDU main housing
 - 1 Differential
 - 1 Actuator (hydr. or e-mech.)
- > TWINSTER
 - 2 Couplings integrated into RDU main housing
 - Differential eliminated
 - 2 independent controlled couplings
 - hydraulically actuated
 - 1 Motor Pump Unit
 - 2 Valves

Standard single coupling



Twinstar



Future CO₂ legislation does require high efficient AWD systems

- > Improve drag loss (incl. Active Connect Systems)

Performance

- > Single clutch AWD hang on systems are combined with a standard open differential
 - Traction performance is limited by the open-differential-functionality (e.g. side to side $\Delta\mu$)
 - Drawback is compensated by brake intervention Traction Control Systems (TCS)
 - In μ -split up hill, or if a wheel is lifted - condition, TCS requires high throttle input (engine stall protection) which is usually for a standard driver difficult to handle, because he wants to manage the situation carefully and keeps throttle input low ending up in insufficient traction. Additionally in active TCS mode NVH comfort is reduced and at speeds $\sim >60 - 80$ km/h TCS support is faded out
- > To improve performance, a kind of limited slip function would be a valuable point
 - The unmatched advantage of a limited slip differential is, that it can be locked before the wheel starts to spin and torque is delivered to the wheel where it is needed.
 - Driver feels safe by composed vehicle behavior

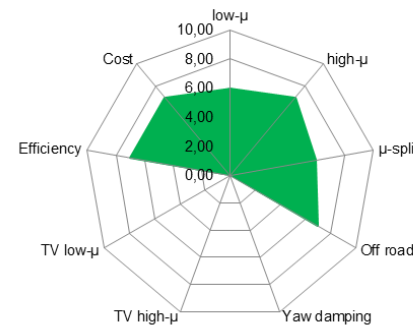
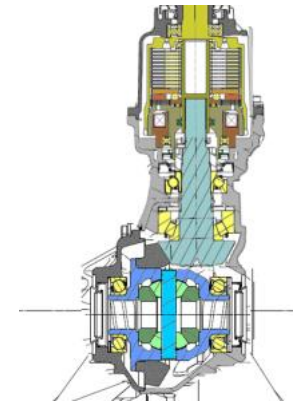
Introduce a passive LSD to an AWD hang on system?

- > Standard AWD hang on system consist of:
 - 1 Clutch (HOC)
 - 1 Actuator
 - 1 ECU
 - Rear Drive Unit with
 - Housing
 - Ring Gear and pinion set
 - Differential
- > Optional: AWD hang on system with passive LSD
 - Open differential exchanged by passive LSD – add:
 - Inner and outer plates
 - Armature
 - Modified differential carrier

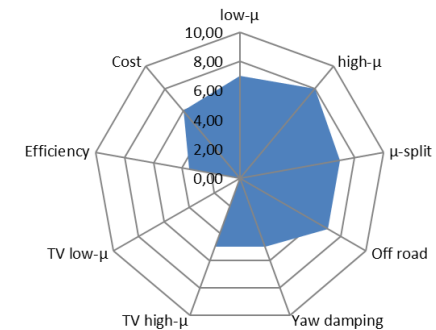
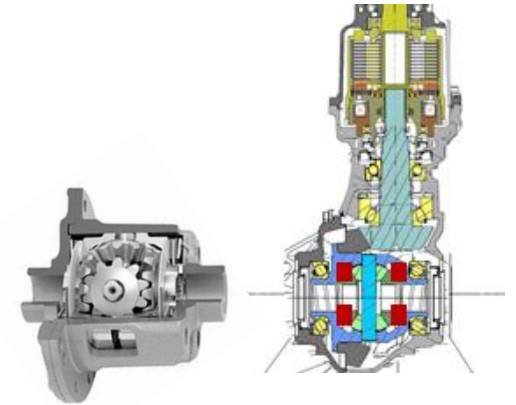
Pro and con by passive LSD

- > Improved traction in on and off road limited by Torque Bias
- > Load dependent understeering
- > No wear compensation over lifetime
- > No thermal protection for passive LSD
- > Not compatible for Active Connect system

Inline single coupling
(Reference)



Inline single coupling
with passive LSD



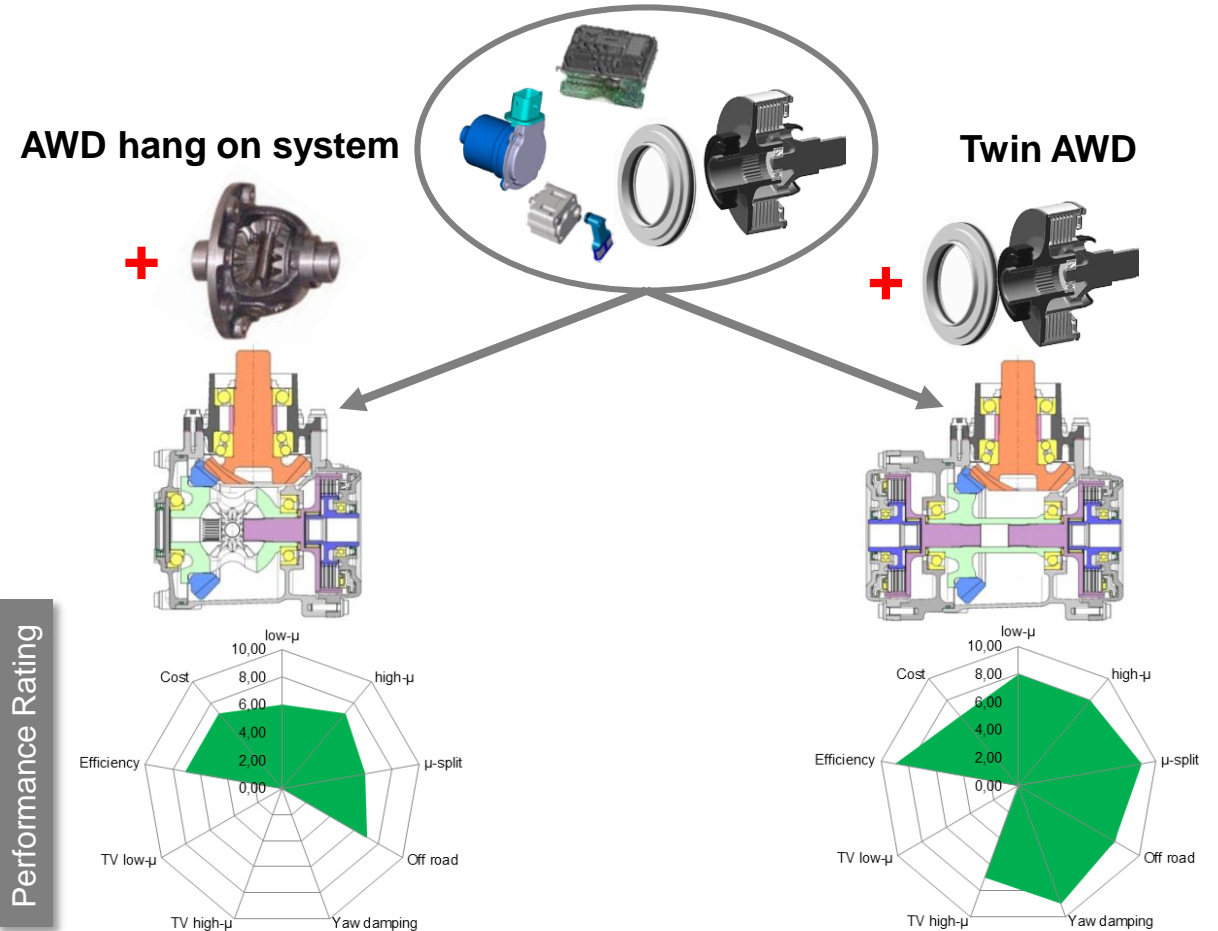
Passive LSD in combination with inline clutch improves performance but overall Performance / Effort ratio is **not** sufficient.

Twin AWD based on side mounted clutch system?

- > Standard AWD hang on system consist of:
 - 1 Clutch (HOC)
 - 1 Actuator
 - 1 ECU
 - Rear Drive Unit with
 - Housing
 - Ring Gear and pinion set
 - Differential
- > Additional components for Twin AWD
 - 1 Clutch added
 - **Differential substituted**
 - **No Valves (no individual clutch control!)**

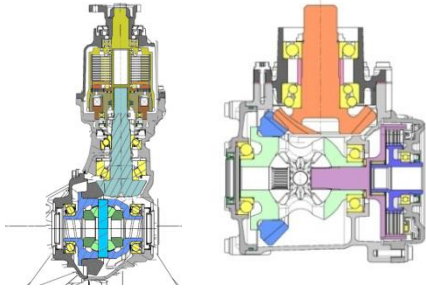
Performance changes by Twin AWD

- > eLSD functionality up to full lock
- > High- μ TV by eLSD
- > Active Connect (no differential drag loss)
- > Adjustable load dependent understeering

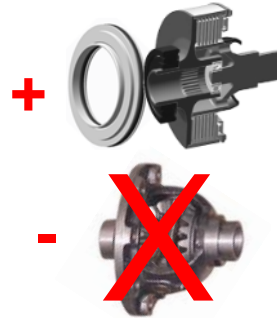


Twin AWD shows a very good Performance / Effort ratio. Would it be attractive for OEMs?

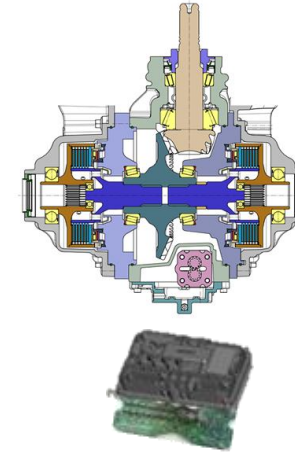
Single Coupling (Reference) Standard AWD-Hang on



Twin AWD



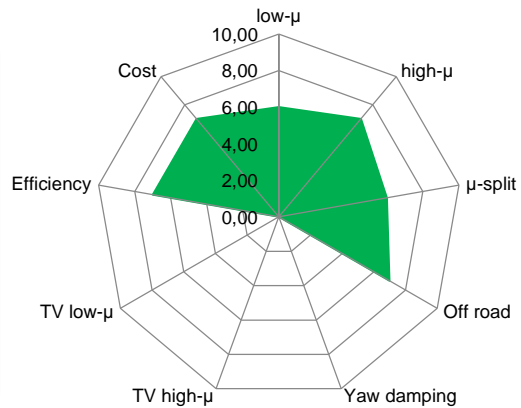
Identical RDU



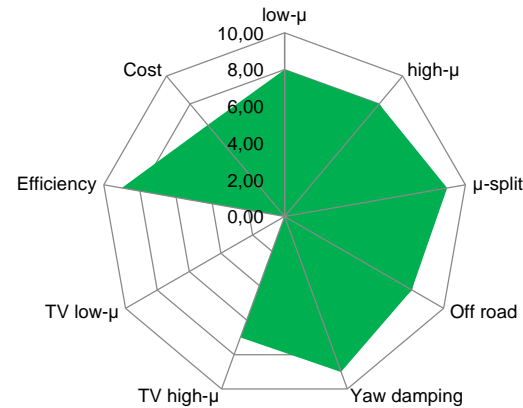
Twinstar



Performance Rating

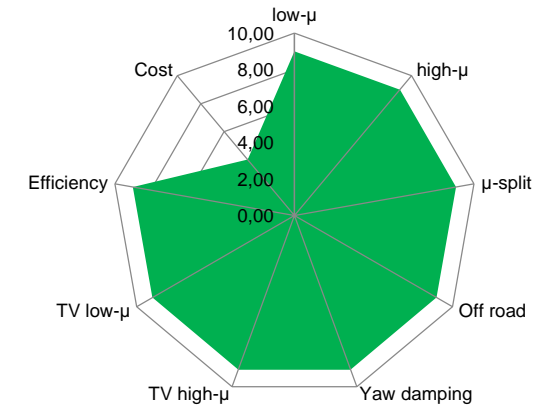


Twin AWD



Improvement by adding one coupling and eliminating open Differential

Performance



Improvement by adding 2 Valves

New product line concept proposal

> Twin AWD standard AWD System

- Rear Drive Unit with
 - Housing
 - Ring gear and pinion set
 - **Differential (eliminated)**
- 2 Clutches
- 1 Actuator (Motor Pump Unit)
- 1 ECU

> Twinster performance

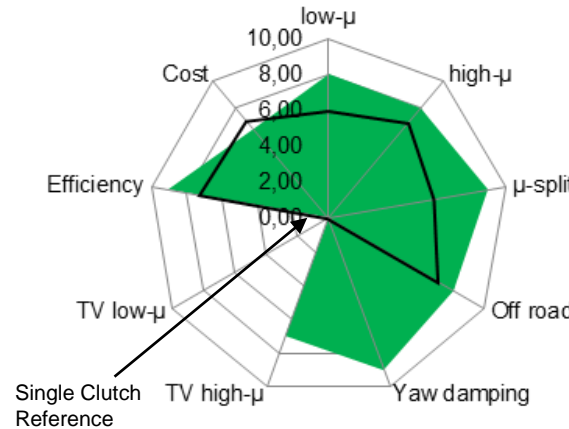
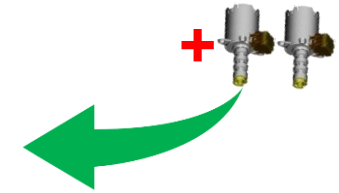
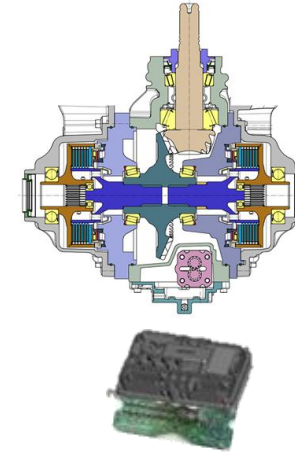
See above and add:

- 2 Valves

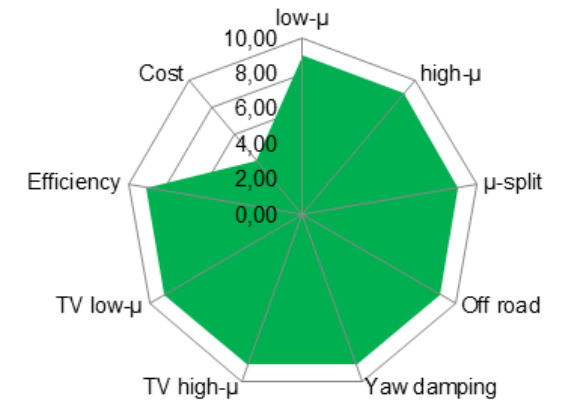
Twin AWD

Identical RDU

Twinster



Improvement by adding one coupling and eliminating open Differential

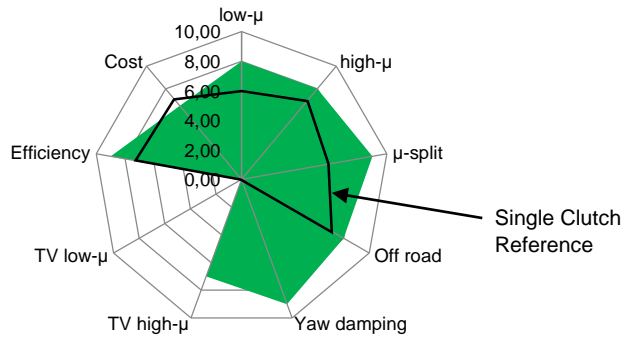


Improvement by adding 2 Valves

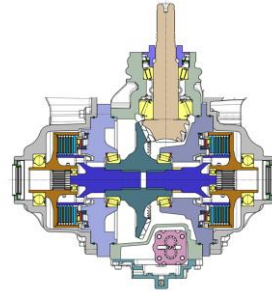
Vision

How can GKN support OEM's on platform strategy?

Twin AWD: focus on cost and mobility



Twinstar: focus on handling



Twinstar RDU
incl. Actuator



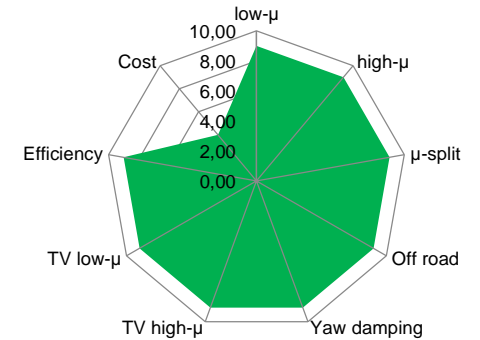
ECU

Standard

Cartridge Valves



Optional



Identical Twinstar RDU hardware and simple, modular actuation (incl. ECU, only 2 valves need to be added)

System Requirements and Performance

Can Twin AWD fulfil functional requirements?

Twin AWD provides hang on clutch and eLSD function in one unit. Left and right clutch are controlled simultaneously. An active controlled system can be very well adapted to driving situations to avoid negative vehicle behavior.

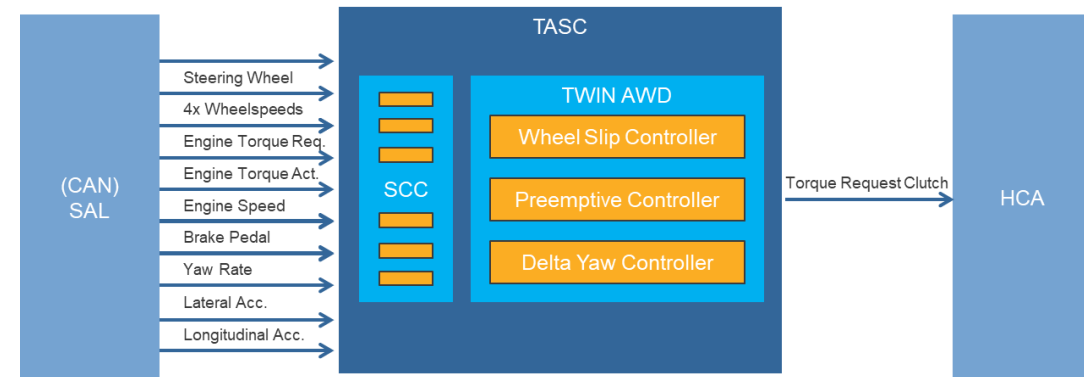
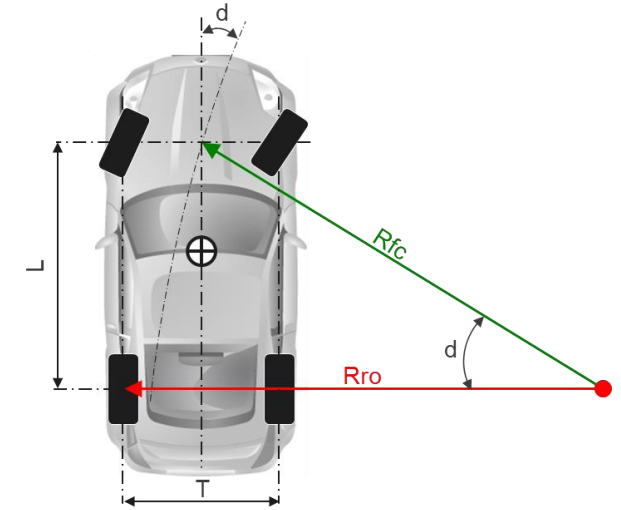
Some (of many) questions to be answered:

Functions:

- > Response time
 - Clutch fill time sufficient?
- > Accuracy of left and right clutch (no individual control)
 - Sufficient accuracy left right if clutch shimming or wear is different?

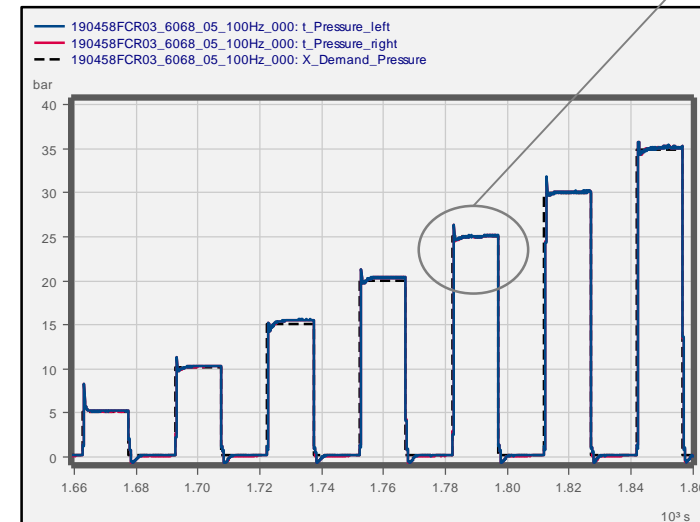
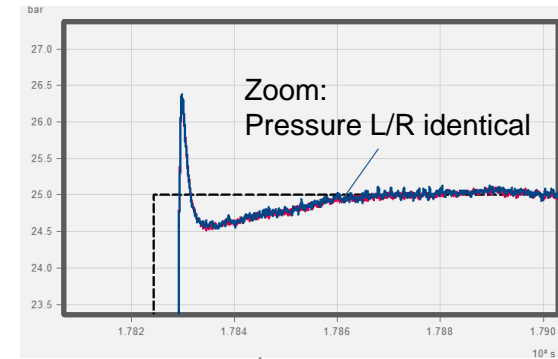
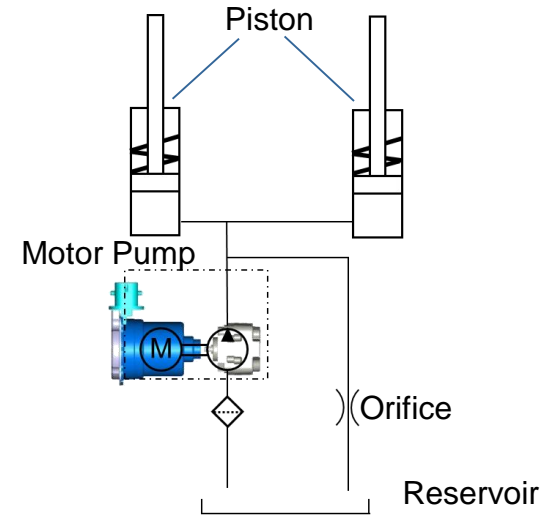
Vehicle performance:

- > Is the system functional safety compatible?
 - Fail safe open
 - Acceleration on split- μ (Yawcontrol)
 - ABS/ESP intervention
- > Because of no individual clutch control how to avoid:
 - Driveline wind up during parking maneuvers?
 - too much understeering during steer in and cornering in general?



Hydraulic actuation was chosen for Twin AWD system because of:

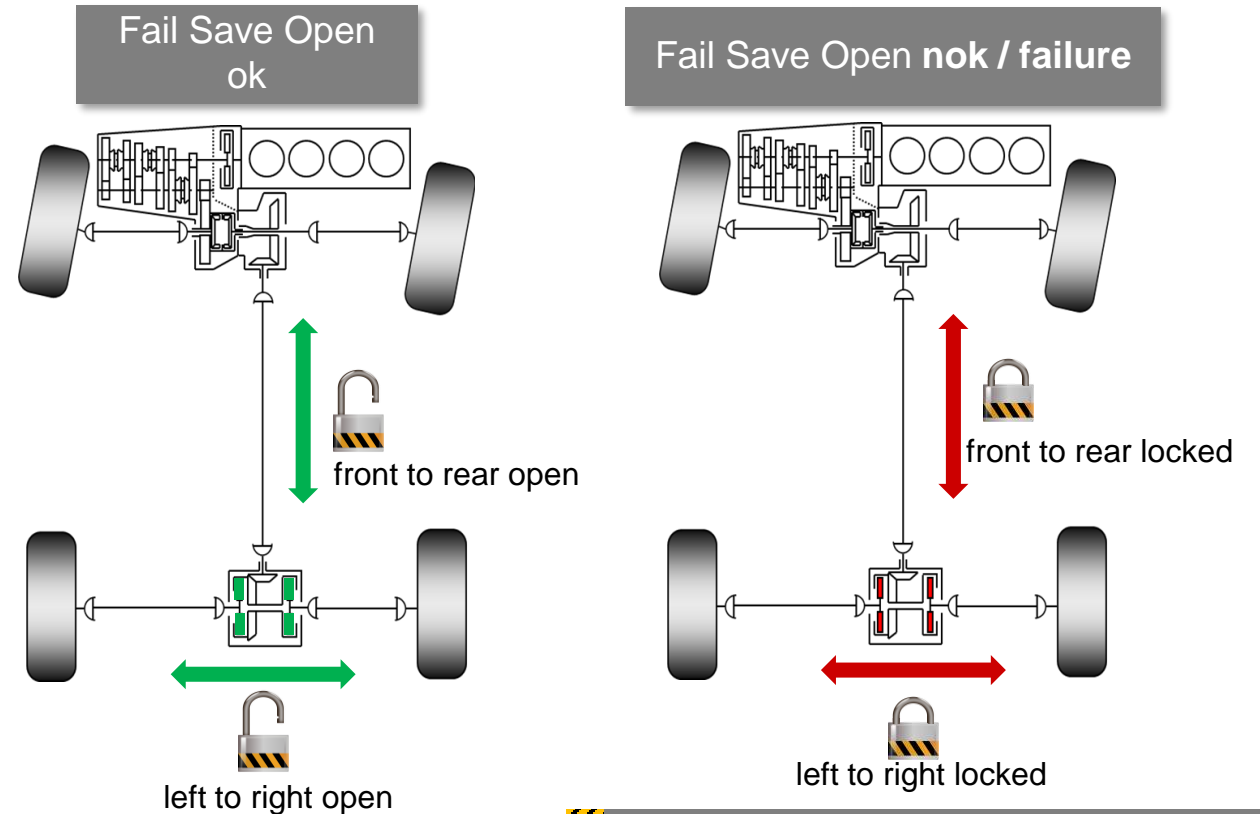
- > Hydraulic actuation derived from Twinster system
 - Already validated components, in production
- > Single motor pump actuator supplies both clutches
 - Pump volume flow characteristic is sufficient enough to pressurize two clutches in parallel, providing acceptable response times
 - Twin AWD is a direct force controlled system (hydr. pressure → actuation force) and guarantees equal torque transfer.
 - Hydraulic actuation and Z-Disc Clutch arrangement ensures robustness and simultaneous torque transfer left / right even if clutch shimming or wear on clutches is different
- > Fail safe open requirement is ensured by hydraulic design
 - If pump current is off, pressure is released by leaking back to reservoir via orifice and pump



Key functional test: response time and accuracy measurement

Fail safe open is a basic requirement for AWD hang on clutch systems

- > Twin AWD, as one system, provides front to rear axle and rear left- to right wheel torque distribution
- > During braking or ABS/ESP intervention, wheels need to be decoupled (clutch open demand), to provide braking performance with best stability
- > If system is in a failure mode and fail safe open status will **not** be reached:
 - driveline wind up during cornering occurs
 - damage of AWD components possible
 - during braking or ABS/ESP intervention, vehicle can become instable → safety critical.



By locking front to rear and left to right (rear):

- independent brake distribution front/rear canceled
- rear left / right brake distribution can not follow ABS „select low“ control principle

Fail Safe Open ok



FUSI Investigation on vehicle level Twin / Twinster AWD-System

- Test: Braking on split- μ (closed loop test)
- Fail safe open ok
 - Vehicle controllable during braking event
- Fail safe open not ok (failure)
 - Vehicle not controllable during braking event

Fail safe open is a product safety relevant requirement!

Fail Safe Open nok / failure



By smart control algorithms (corner detection etc.) system compensates for parking / tight cornering maneuvers and corner understeering on low- μ

In comparison to single clutch hang on systems:

- > Very high mobility traction potential in on and off road
 - μ -split, one wheel in the air (no TCS intervention on rear wheels)
 - 100% cross axle locking torque
- > Very predictable and stable, safe behavior on low- μ surfaces
- > Throttle off yaw damping (reduced ESP intervention)
- > Torque Vectoring capability at lateral acceleration $> \sim 0.3$ g
- > Best efficiency by lowest drag loss in open
- > Active Connect compatible



Potentials to become a cost competitive Twin AWD-System

Potentials to become a cost competitive Twin AWD-System

A close cooperation between Engineering (Hardware, SW, EE), Manufacturing Engineering (Plant) and Procurement with “design to cost” and “design for manufacturing” approach was set up to identify potentials:

- > Scaling effects by reduced complexity and increased number of standardized parts
 - Same parts deriving from Twinstar system already in production on AWD programs
 - Clutch packs, disc carriers, ECU, SW controls, hydr. Pump, e-motor, etc.
- > Simplification of axle design by
 - One main axle housing with standardized parts:
 - Axle housing can be optimized for Twin clutch integration (no need to take care for open differential variant)
 - Identical clutches, covers, bearings, sealings, ring gear and pinion set
 - Same ECU and wiring to vehicle connection
 - Production line effort reduced (standardized assembly- and EOL stations)
 - Differentiation by additional plug in cartridge valves for optional Twinstar performance variant
- > Integration on OEM side becomes easier too
 - One RDU Package only
 - Simplified integration into vehicle / other control systems (e.g. ABS / TCS / ESP)

- > Task was to gain performance improvements on standard AWD hang on systems with lowest cost impact
- > Complexity and cost reduction reached by establishing a standard Twin clutch axle concept with single actuator, instead of a “single clutch with optional Twinster approach”
- > By substitution of the open differential, adding a second clutch pack and introducing smart software control algorithms, Twin AWD provides best in class mobility and handling performance*.
- > Twin AWD could become the next generation of standard AWD hang on Systems

*Concept vehicles will be presented on the ride and drive event:

Off Road track: Jeep Renegade Twin AWD

Handling track: Fiat 500X Twinster performance

The diagram shows a top-down view of a vehicle chassis with various components highlighted in yellow and blue. Below the chassis are two comparison charts and a hardware diagram.

Feature	Twin AWD (Standard)	Twinster (Optional)
Focus	Cost and mobility	Handling
Hardware	Single actuator (incl. ECU)	Two cartridge valves (incl. ECU)
Efficiency	High	Low
Cost	Low	High
Off-road	High	Low
TV high	High	Low
TV low	High	Low
Y-axis damping	High	Low
Single Clutch Reference	High	Low

Identical Twinster RDU hardware and simple, modular actuation (incl. ECU, only 2 valves need to be added)

Thank You



Questions?