

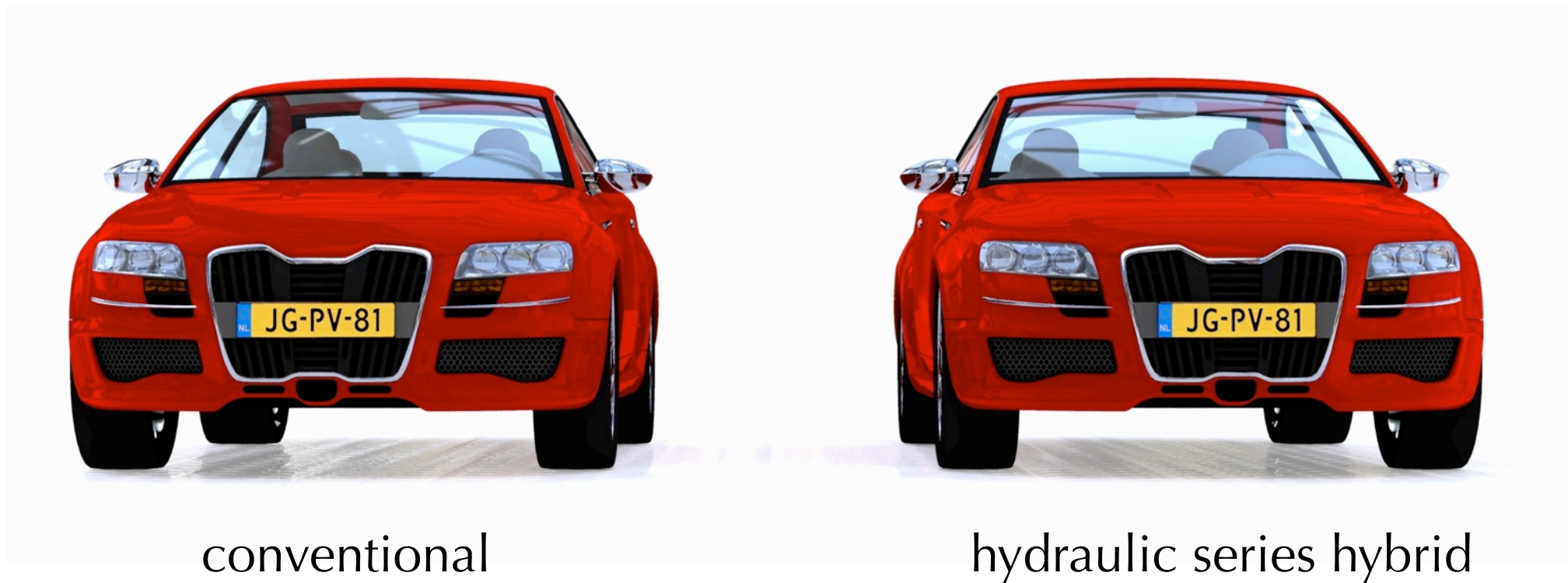
a hydraulic transformer with a swash block control around three axis of rotation



dr. ir. Peter Achten

8.IFK Dresden
March 28, 2012

conclusions



- < 50% fuel consumption
- < 50% CO₂-emission
- no weight increase
- NVH is not an issue

conclusions



conventional



hydraulic series hybrid

< 50% fuel consumption

< 50% CO₂-emission

no weight increase

NVH is not an issue

conclusions



< 50% fuel consumption

< 50% CO₂-emission

no weight increase

NVH is not an issue

What went wrong with the hydraulic hybrid?

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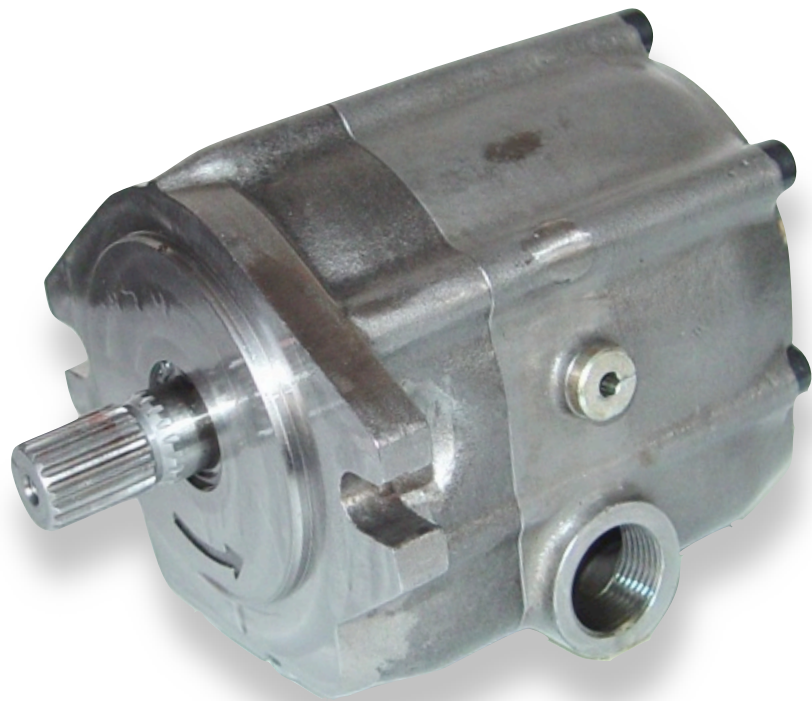
- ❖ not electric
- ❖ poor demonstrators
 - poor efficiency
 - noisy

What went wrong with the hydraulic hybrid?

- ❖ not electric
- ❖ poor demonstrators
 - ▶ poor efficiency
 - ▶ noisy
 - ▶ too expensive

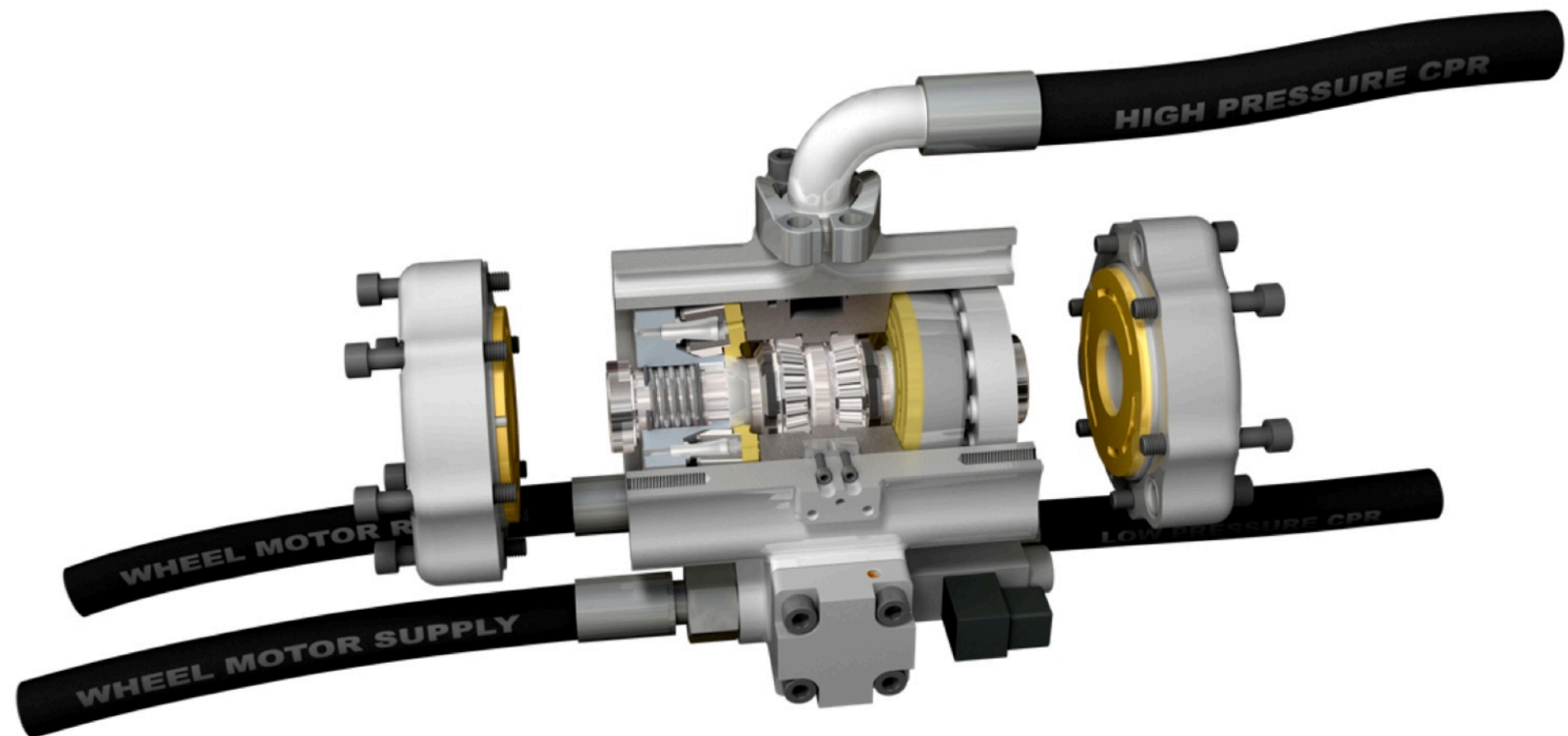
What went wrong with the hydraulic hybrid?

- ❖ not electric
- ❖ poor demonstrators
 - ▶ poor efficiency
 - ▶ noisy
 - ▶ too expensive
- ❖ we were not ready

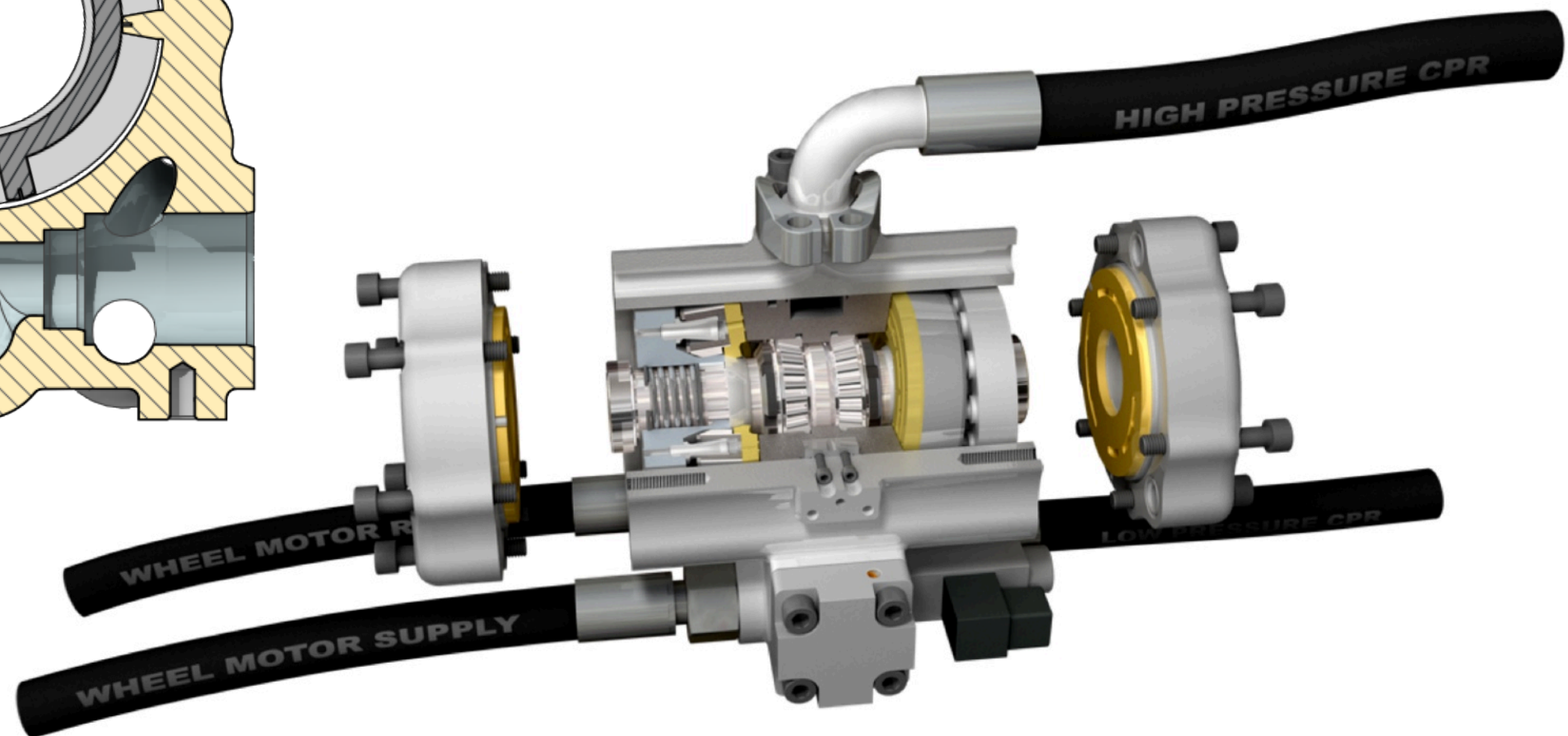
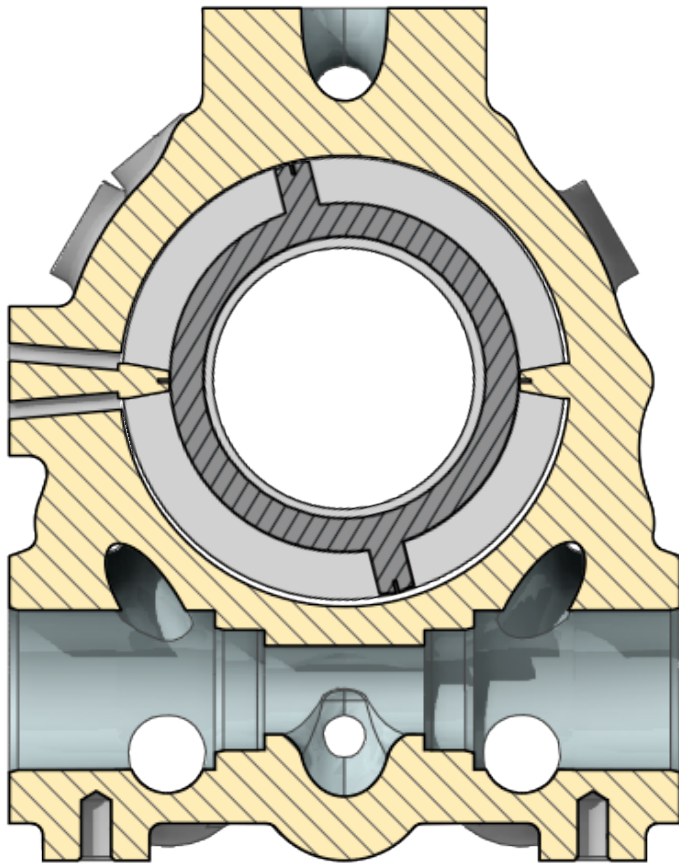


- ❖ compact
- ❖ low torque ripple
- ❖ high starting torque
- ❖ low noise
- ❖ low cost
- ❖ efficient

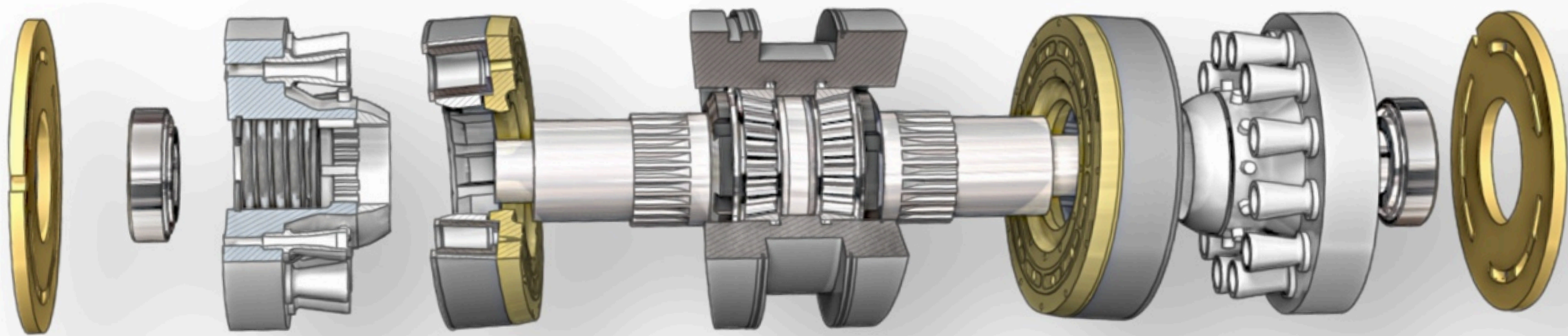
4Q-transformer



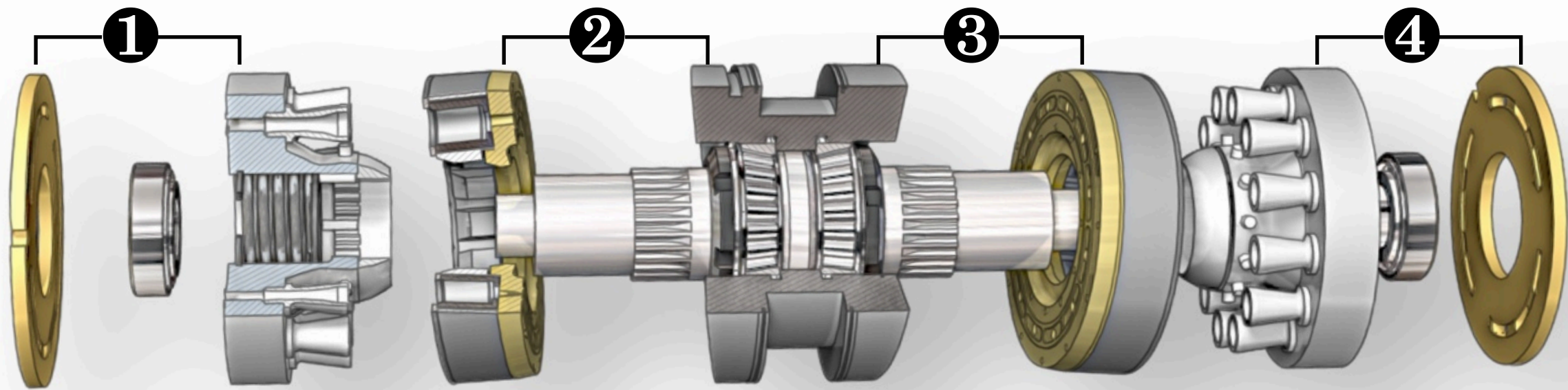
4Q-transformer



4-quadrant transformer

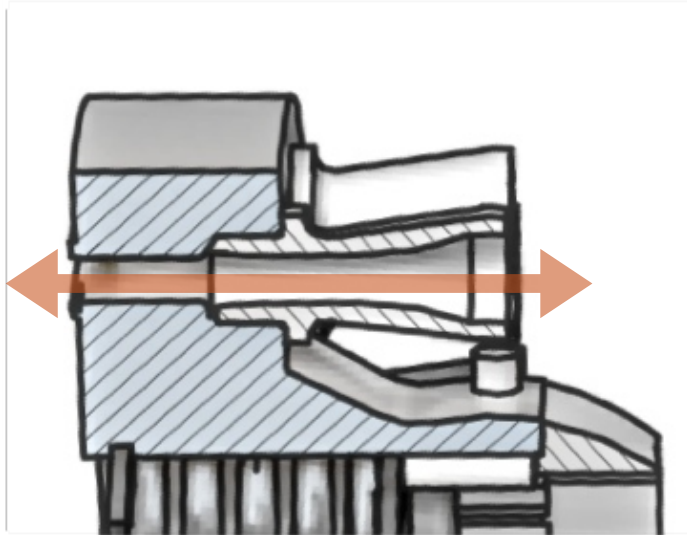
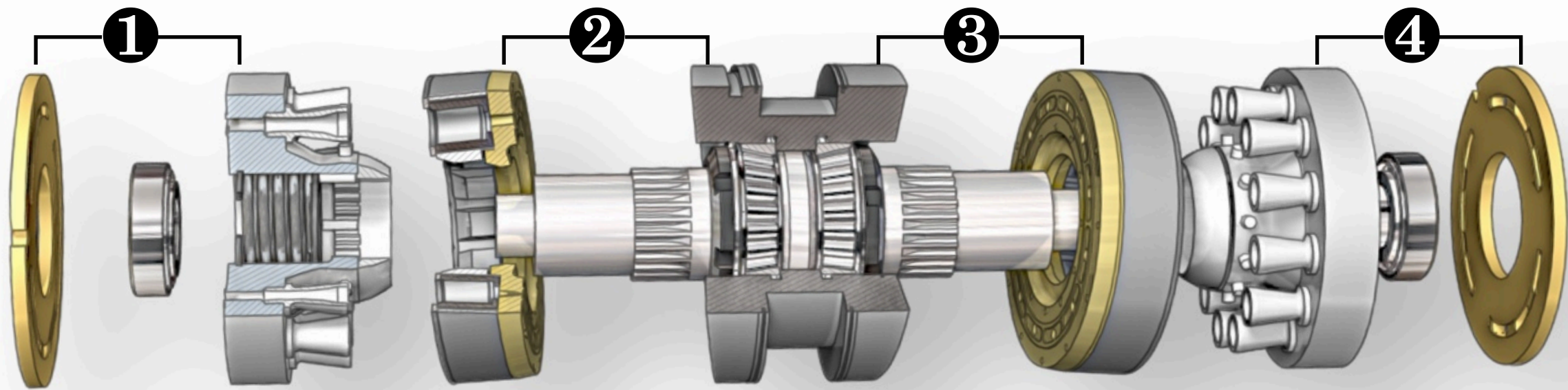


4-quadrant transformer



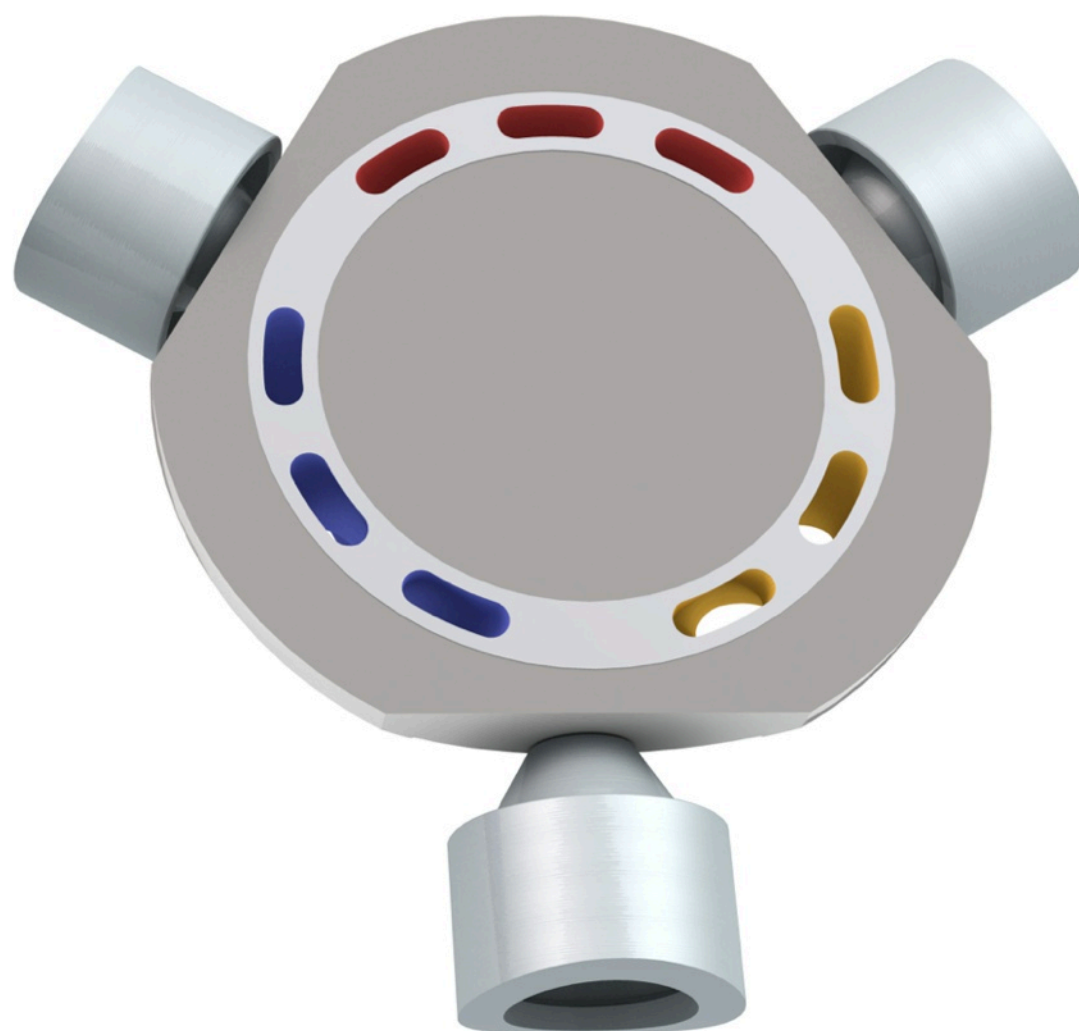
❖ too many (sliding) interfaces

4-quadrant transformer

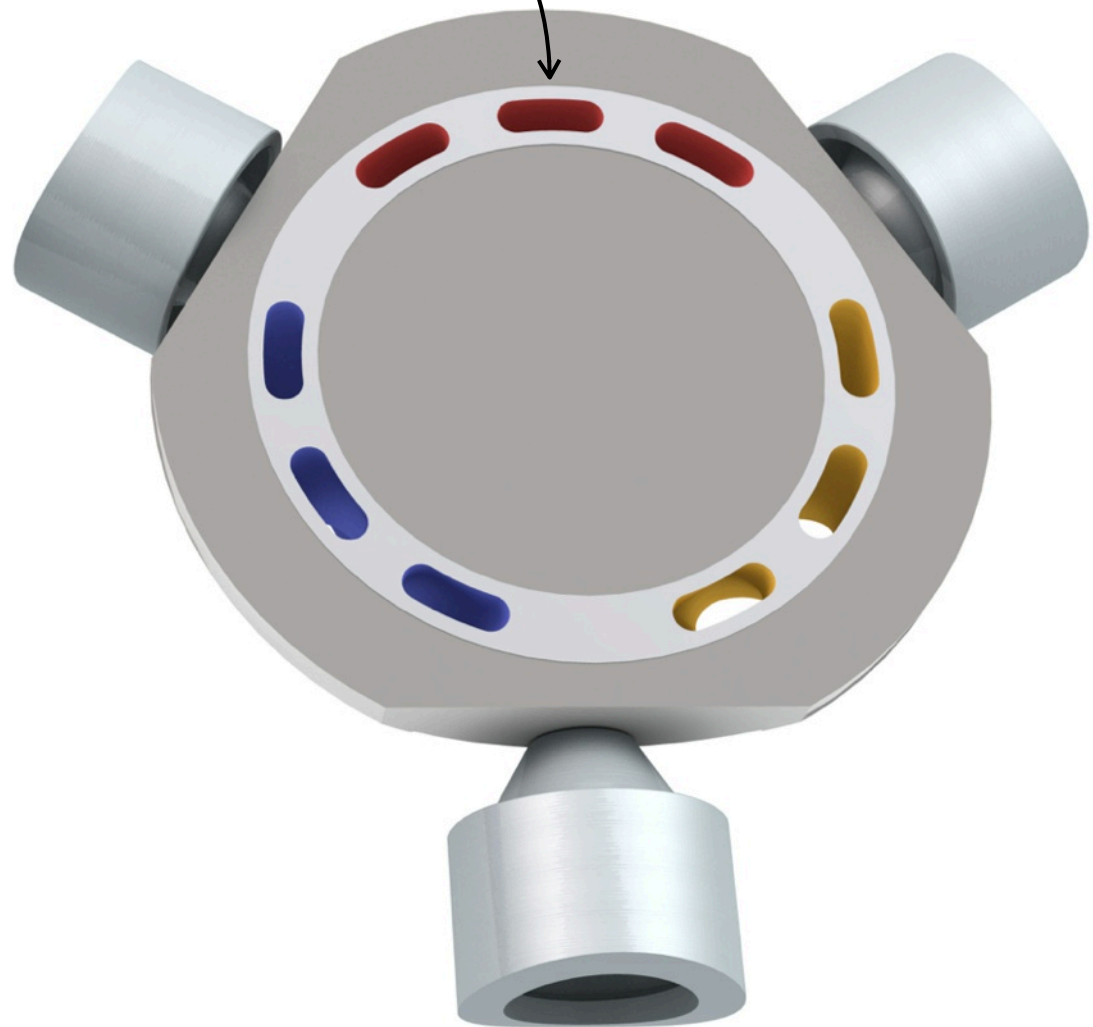


- ❖ too many (sliding) interfaces
- ❖ hollow pistons limit swash angle

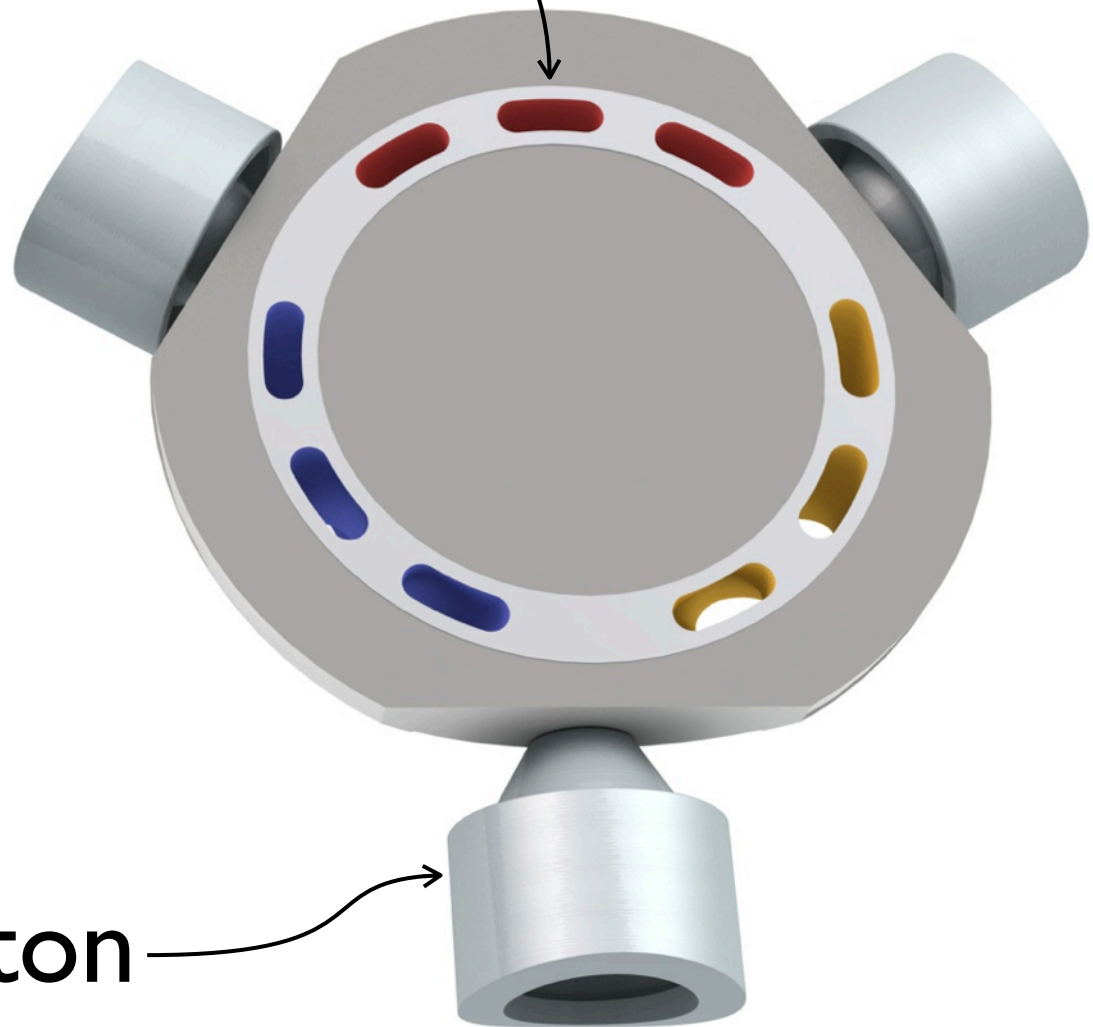
a new design of the hydraulic transformer



port

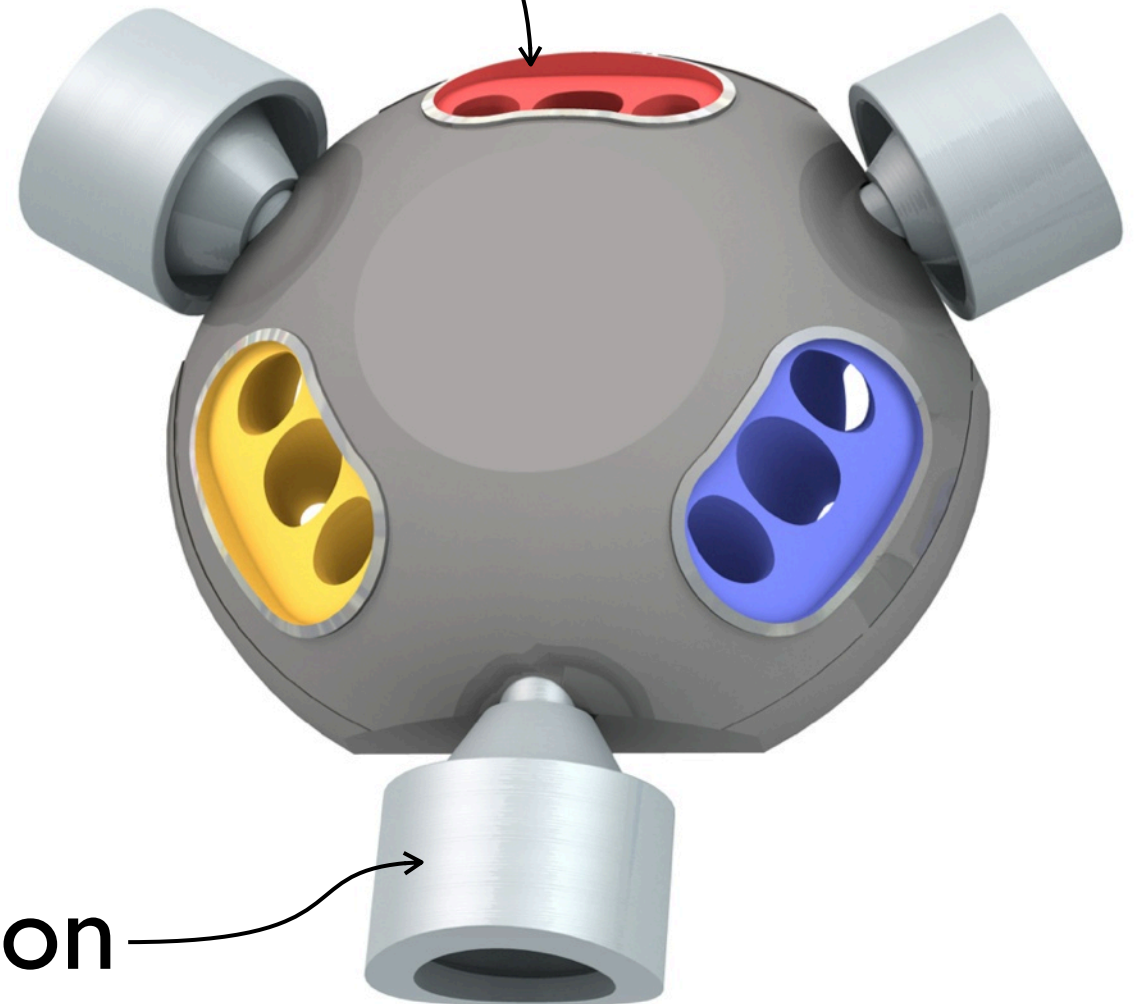


port

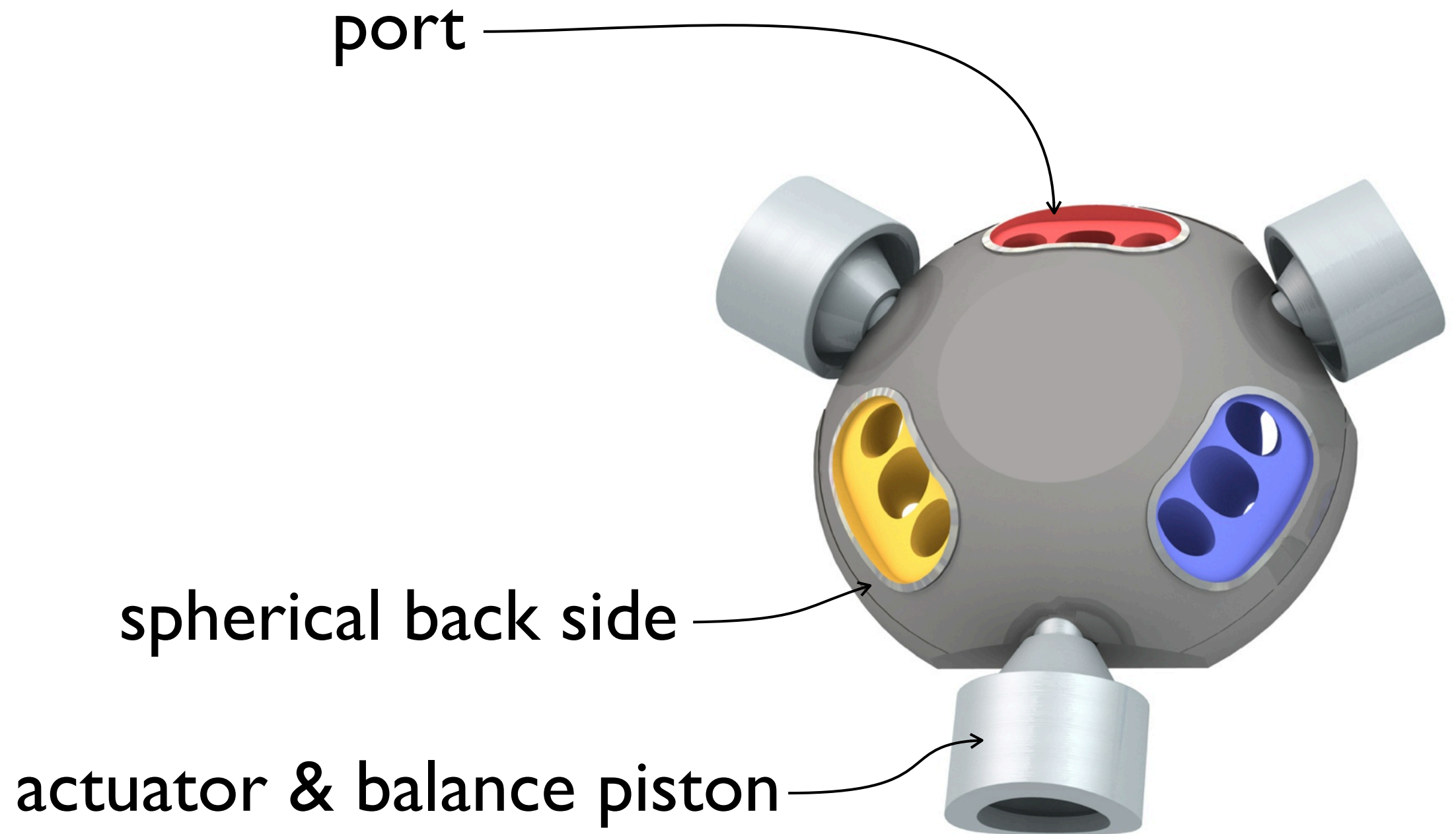


actuator & balance piston

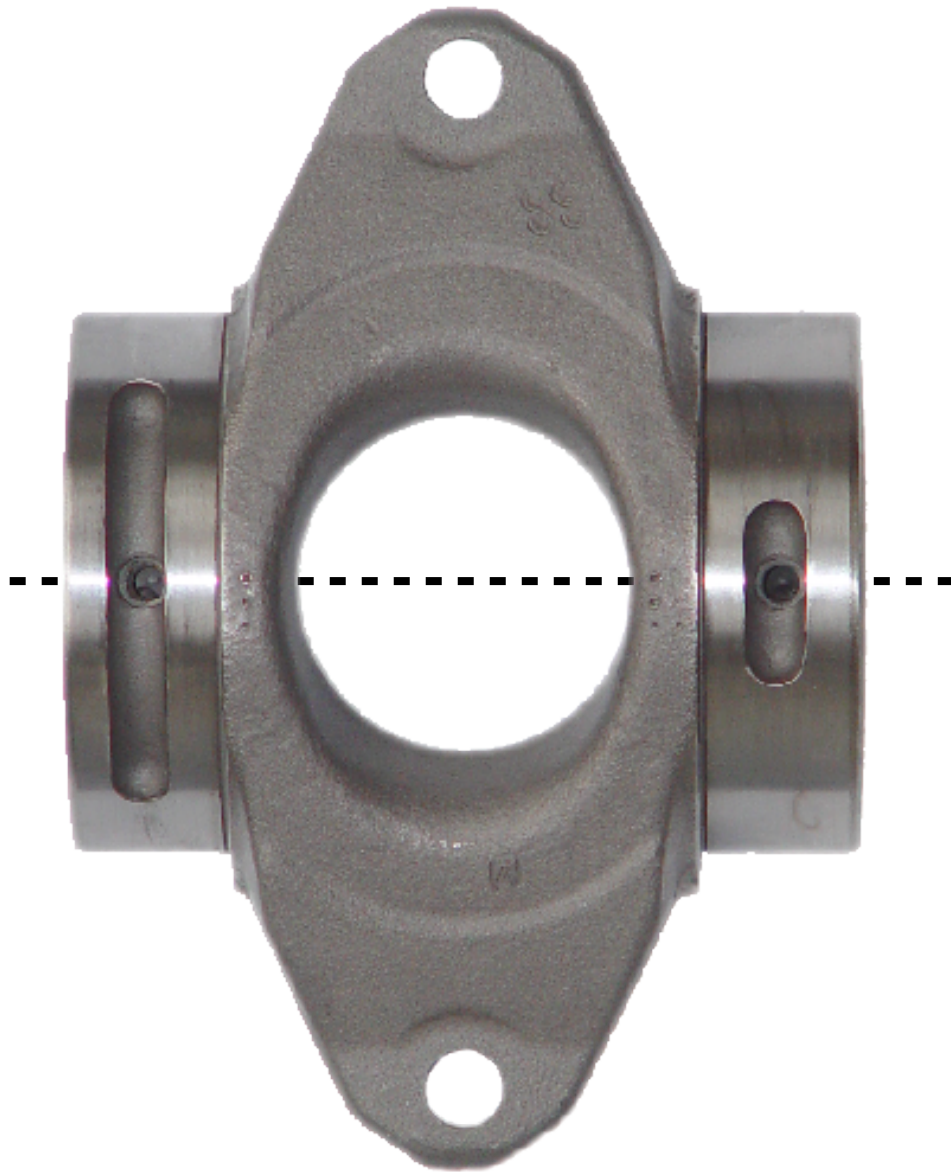
port



actuator & balance piston



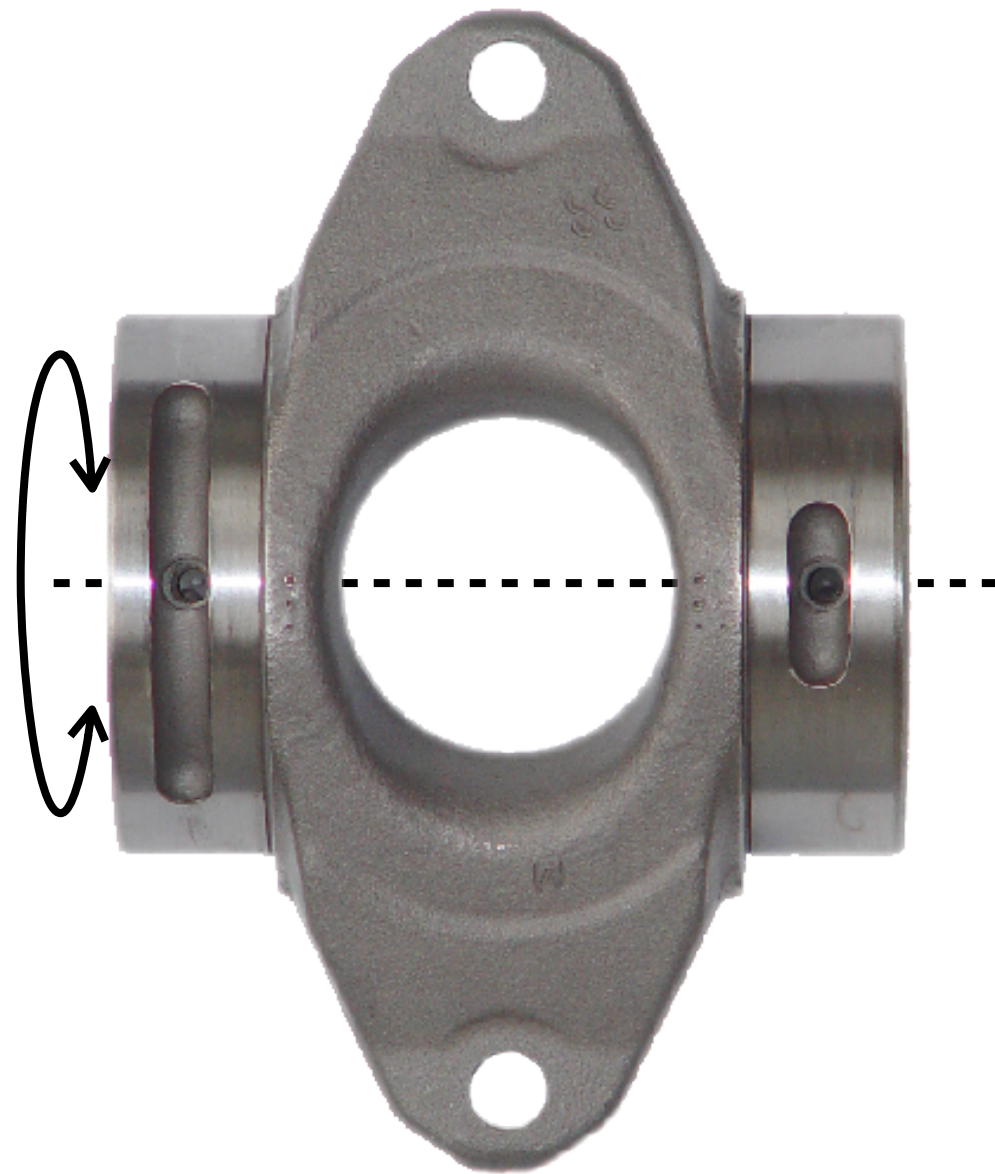
cylindrical bearing



spherical bearing



cylindrical bearing

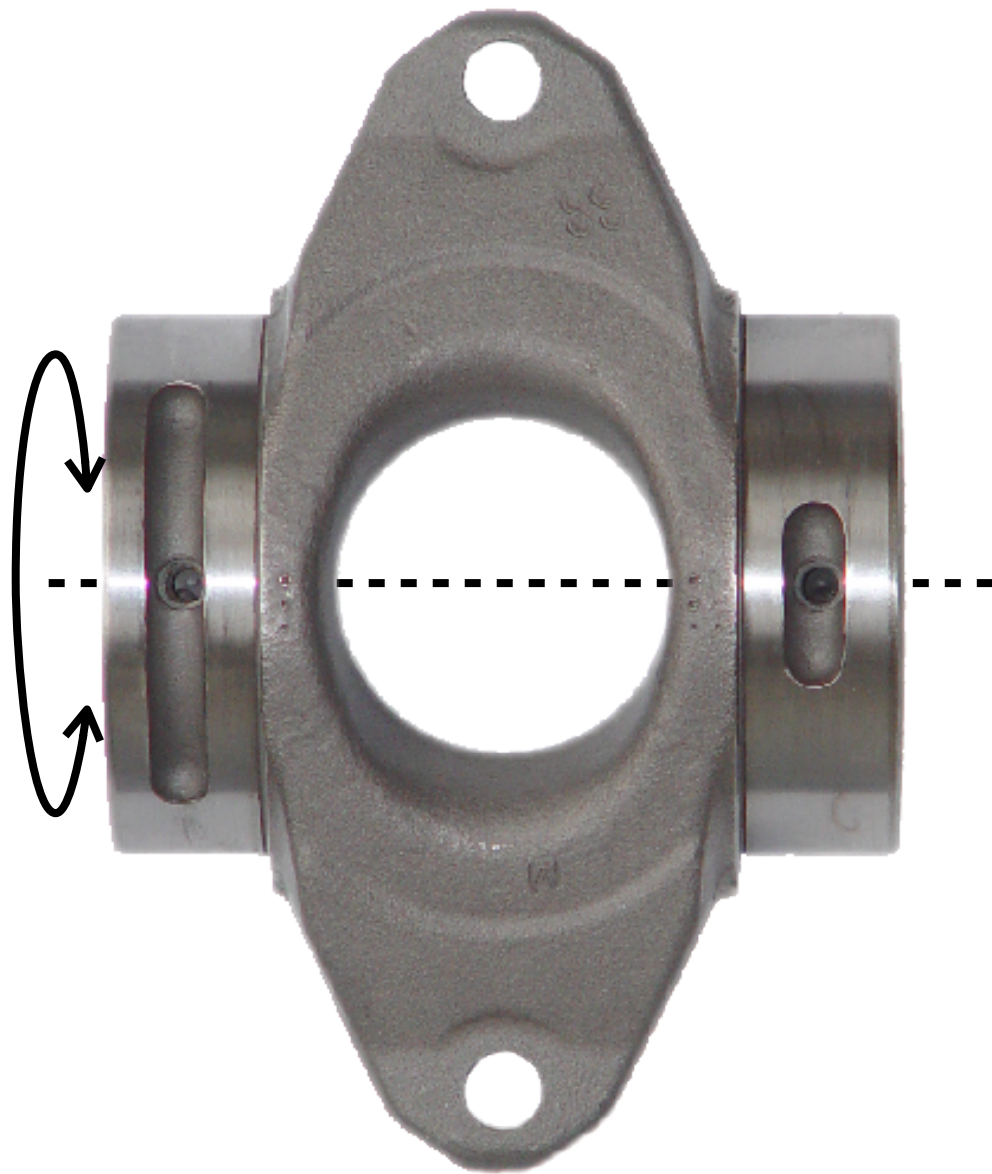


one degree of freedom

spherical bearing

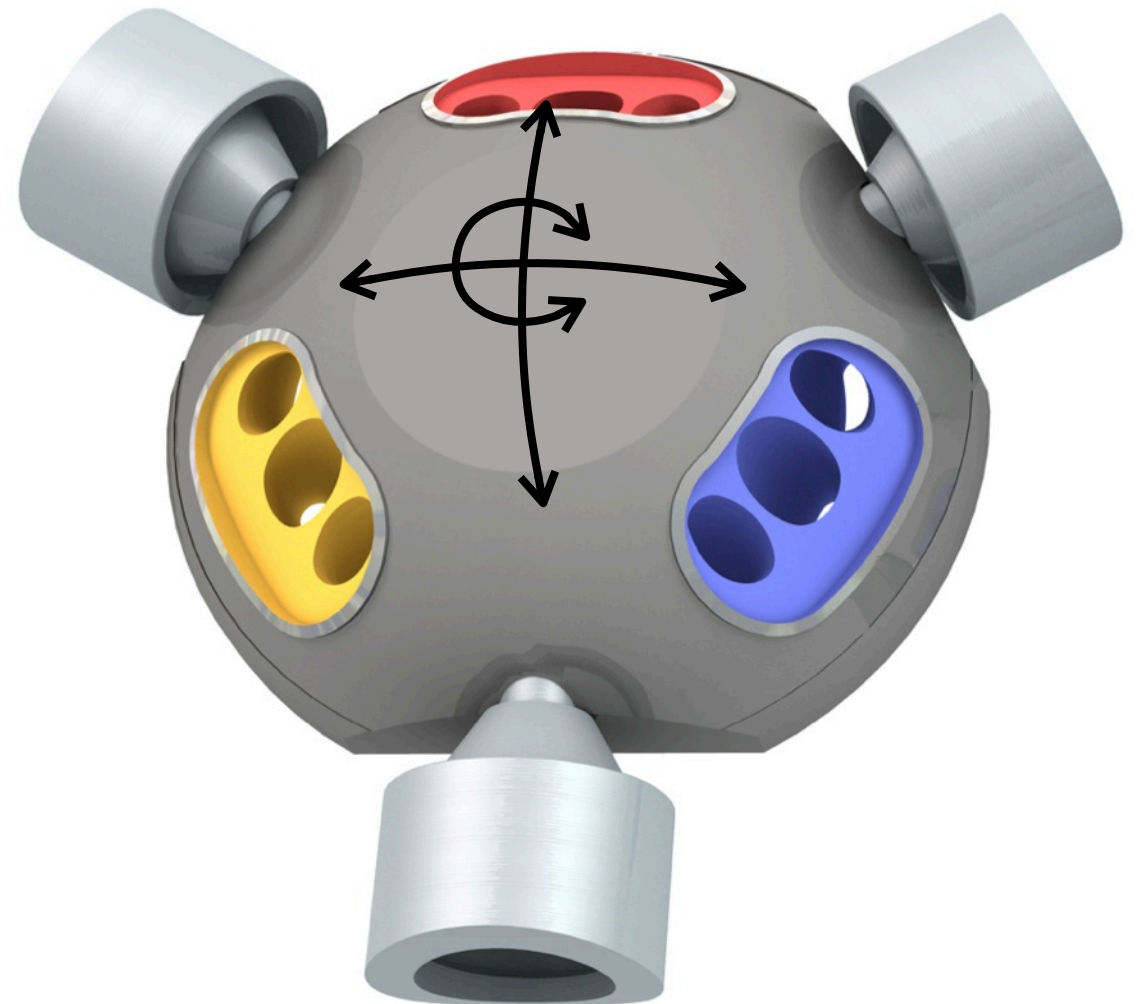


cylindrical bearing



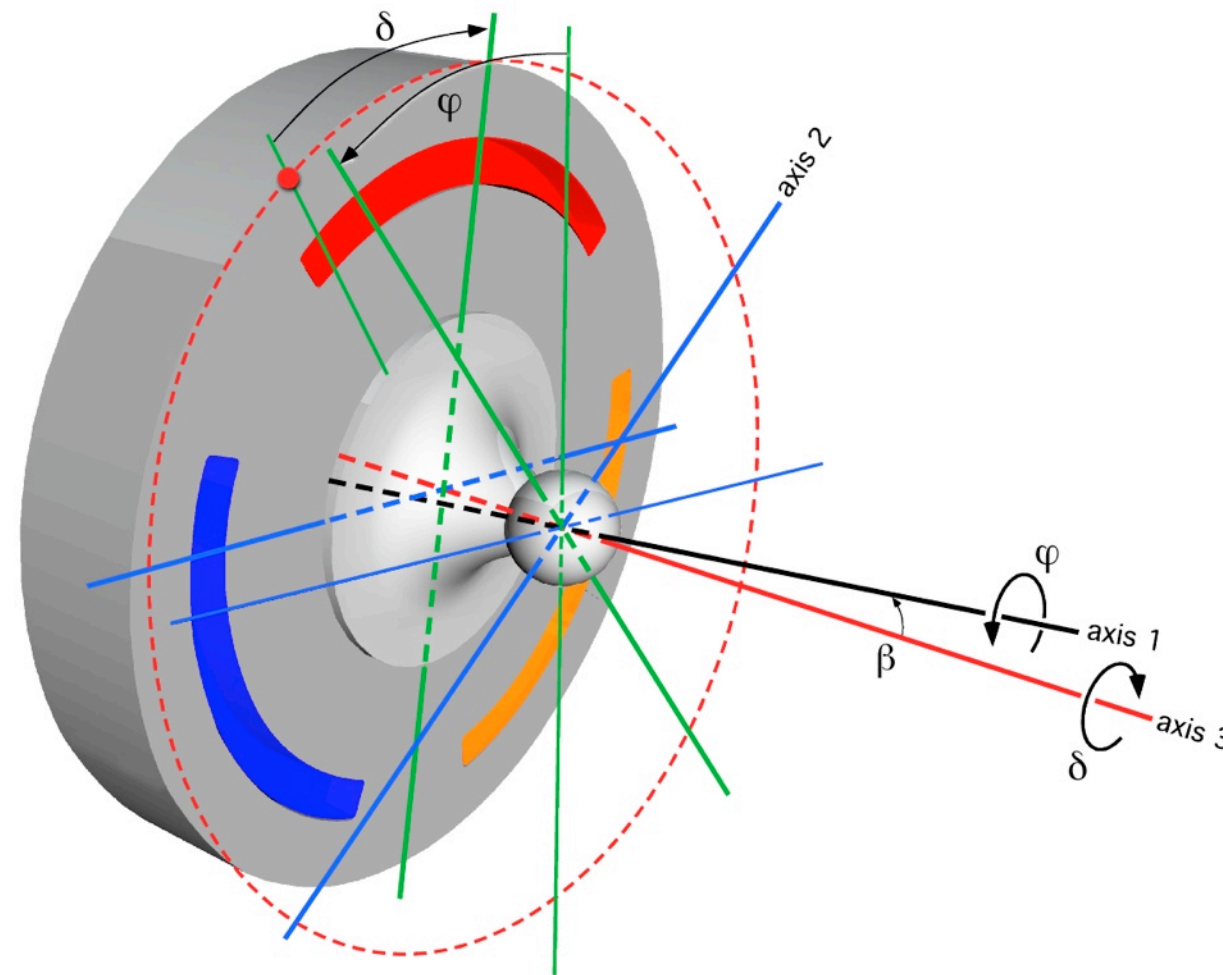
one degree of freedom

spherical bearing



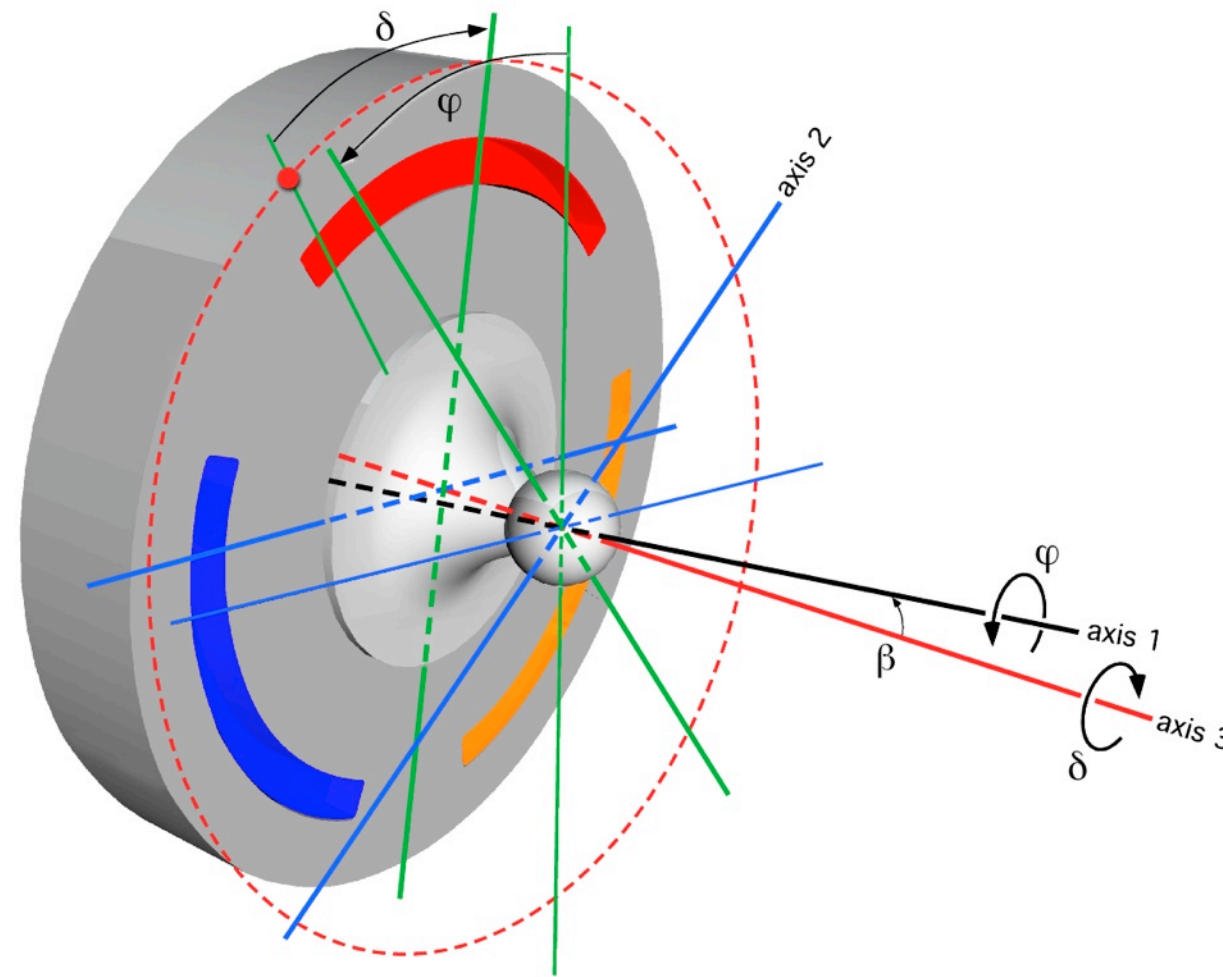
three degrees of freedom

Euler rotations



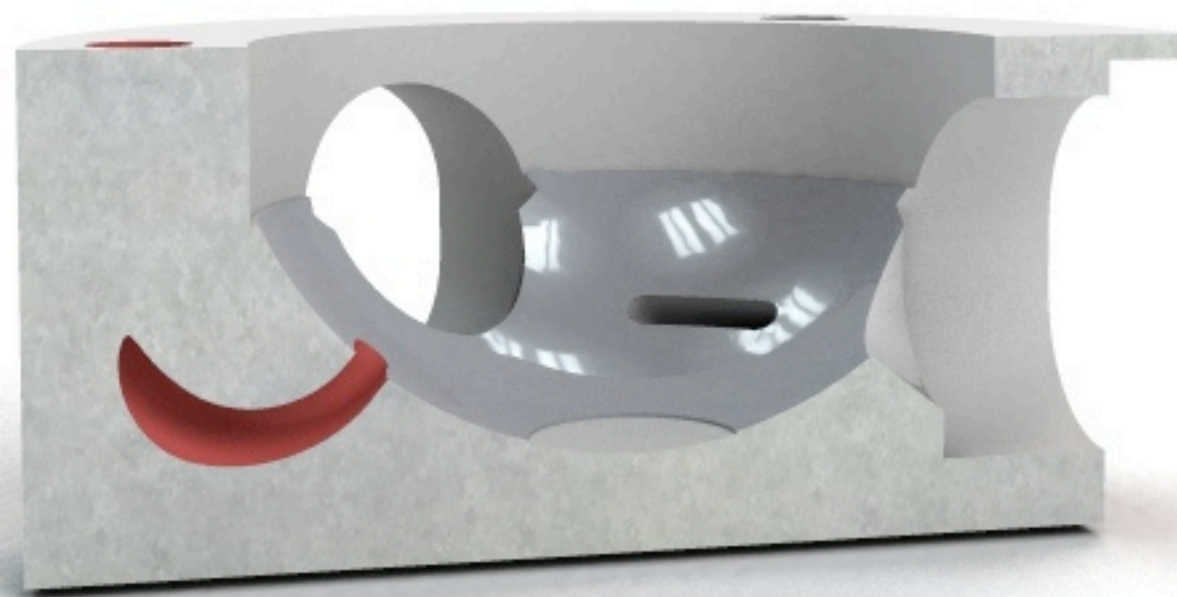
$$\begin{pmatrix} x_2 \\ y_2 \\ z_2 \end{pmatrix} = \begin{pmatrix} \cos(\delta) \cdot \cos(\varphi) - \cos(\beta) \cdot \sin(\delta) \cdot \sin(\varphi) & -\cos(\delta) \cdot \sin(\varphi) - \cos(\beta) \cdot \sin(\delta) \cdot \cos(\varphi) & \sin(\beta) \cdot \sin(\delta) \\ \sin(\delta) \cdot \cos(\varphi) + \cos(\beta) \cdot \cos(\delta) \cdot \sin(\varphi) & -\sin(\delta) \cdot \sin(\varphi) + \cos(\beta) \cdot \cos(\delta) \cdot \cos(\varphi) & -\sin(\beta) \cdot \cos(\delta) \\ \sin(\beta) \cdot \sin(\varphi) & \sin(\beta) \cdot \cos(\varphi) & \cos(\beta) \end{pmatrix} \begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix}$$

Euler rotations

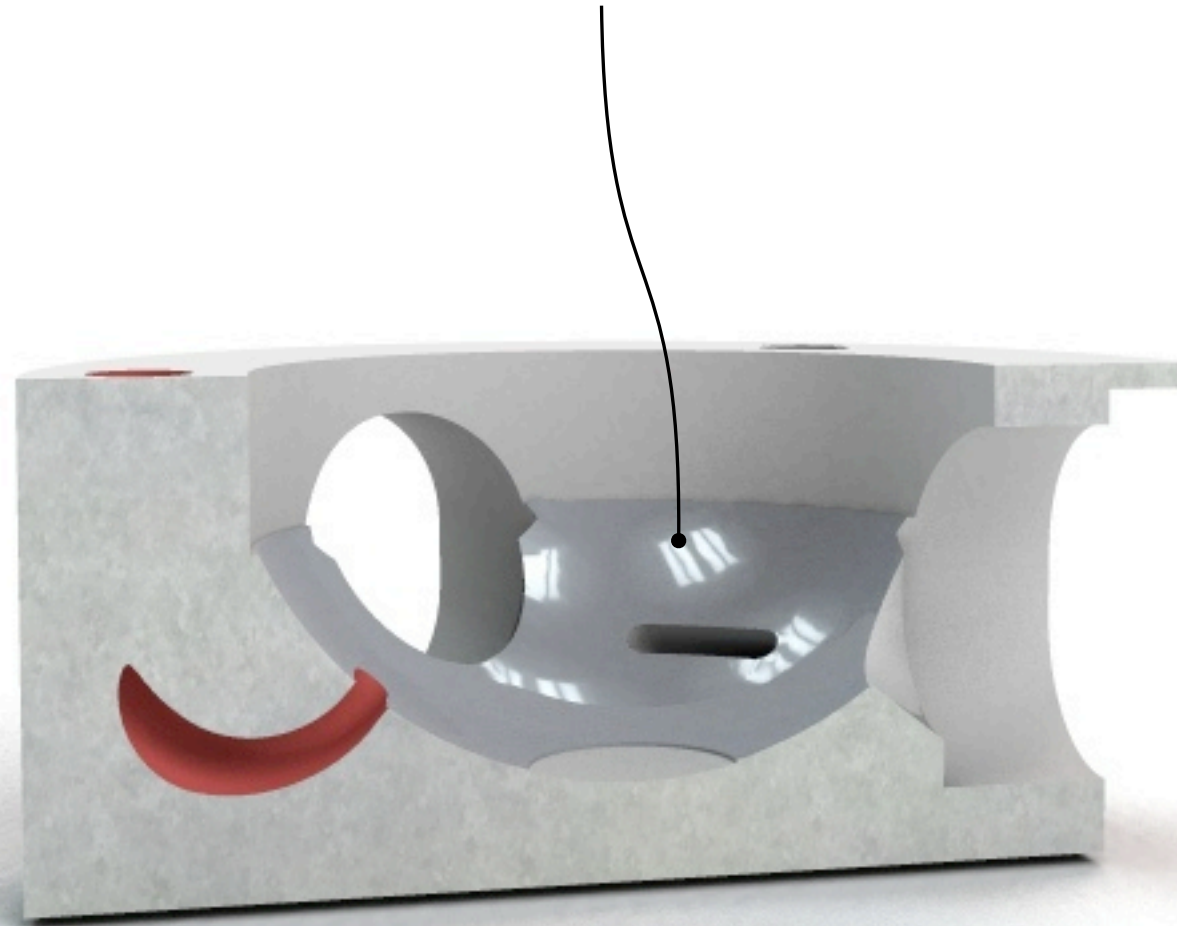


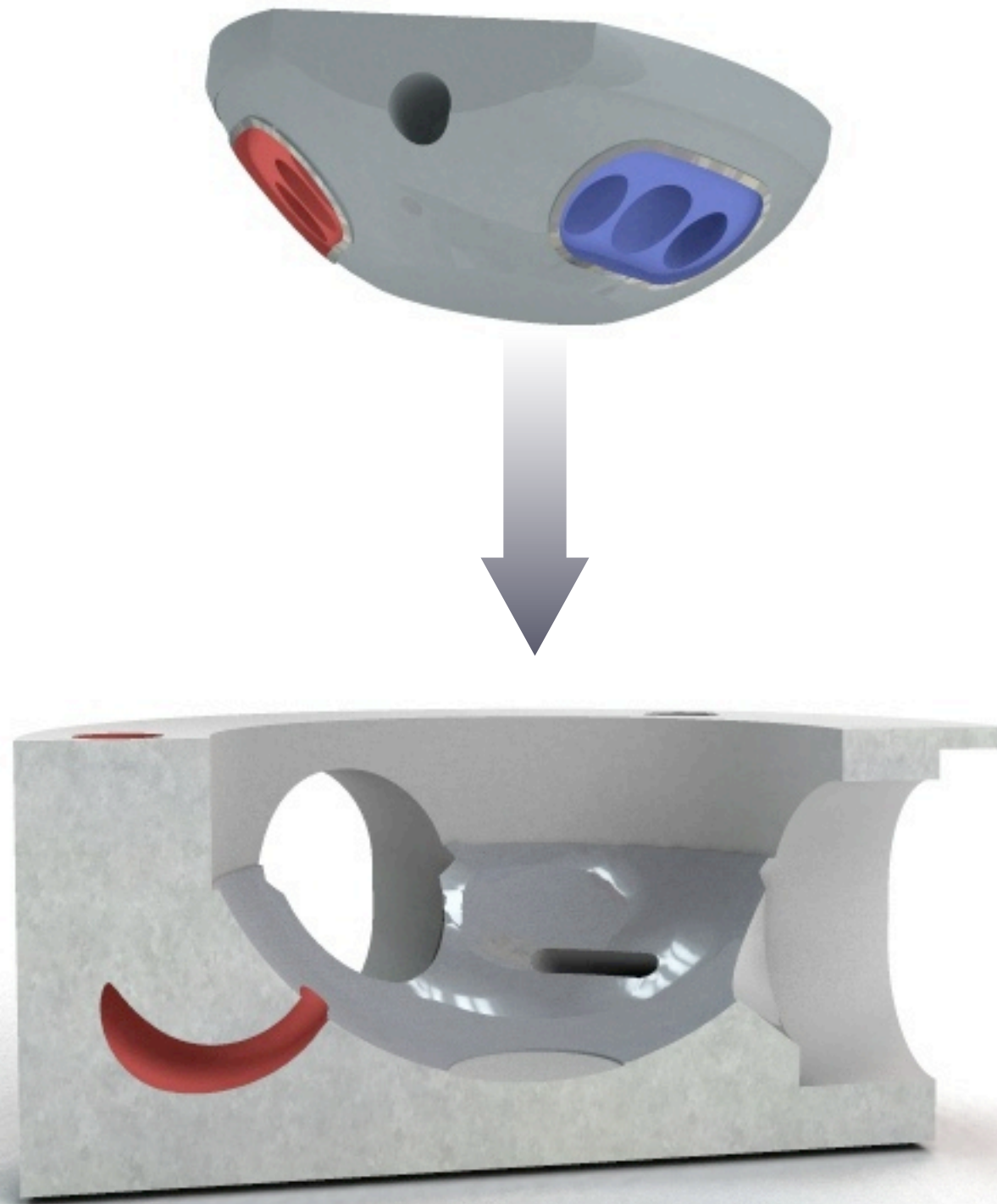
the 'Oiler' transformer

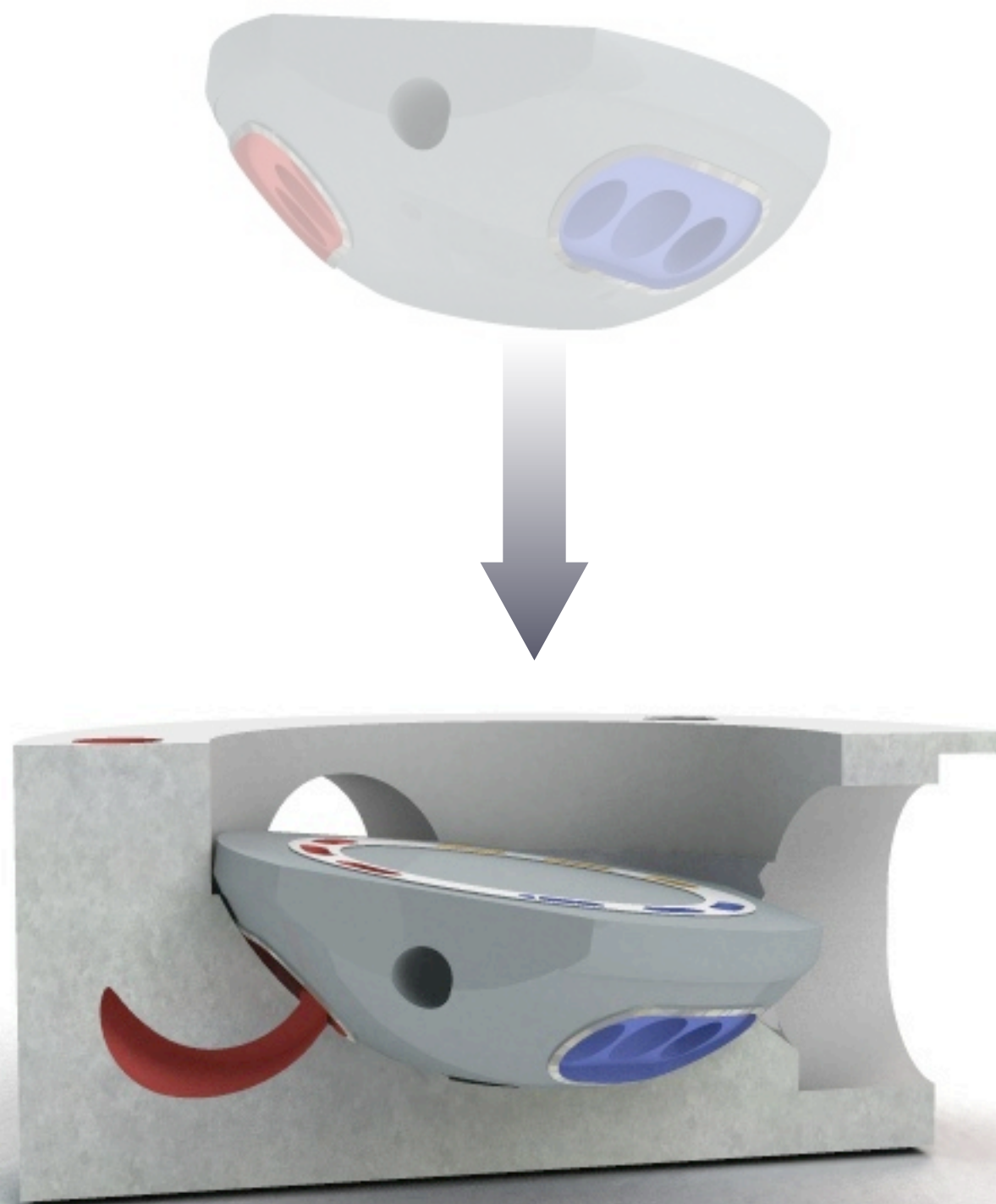
the design

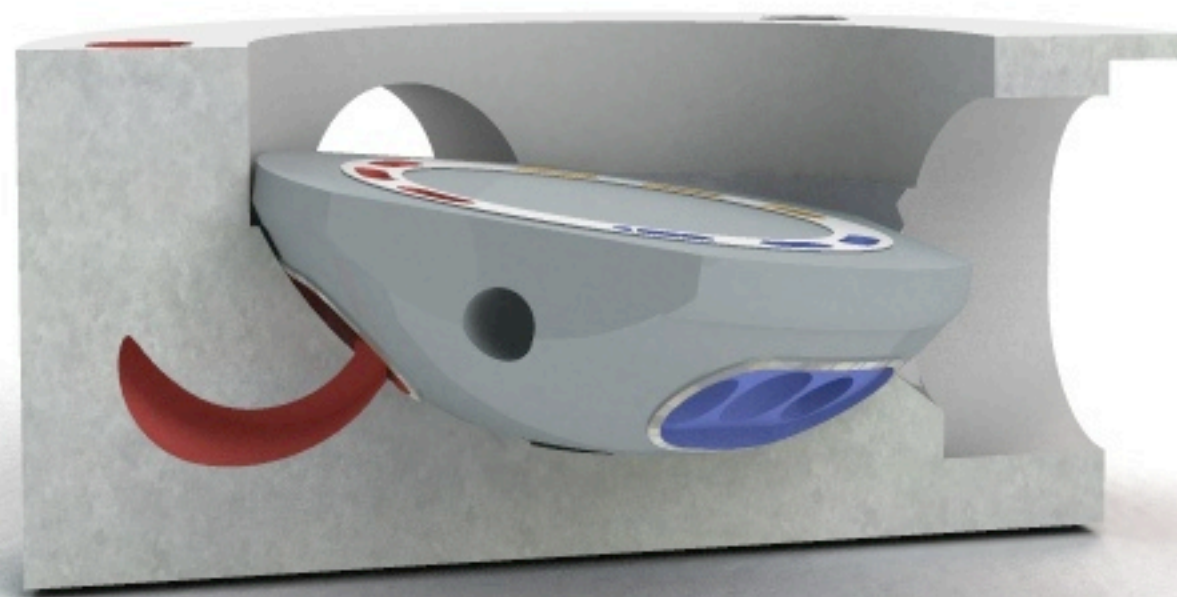


spherical bearing surface

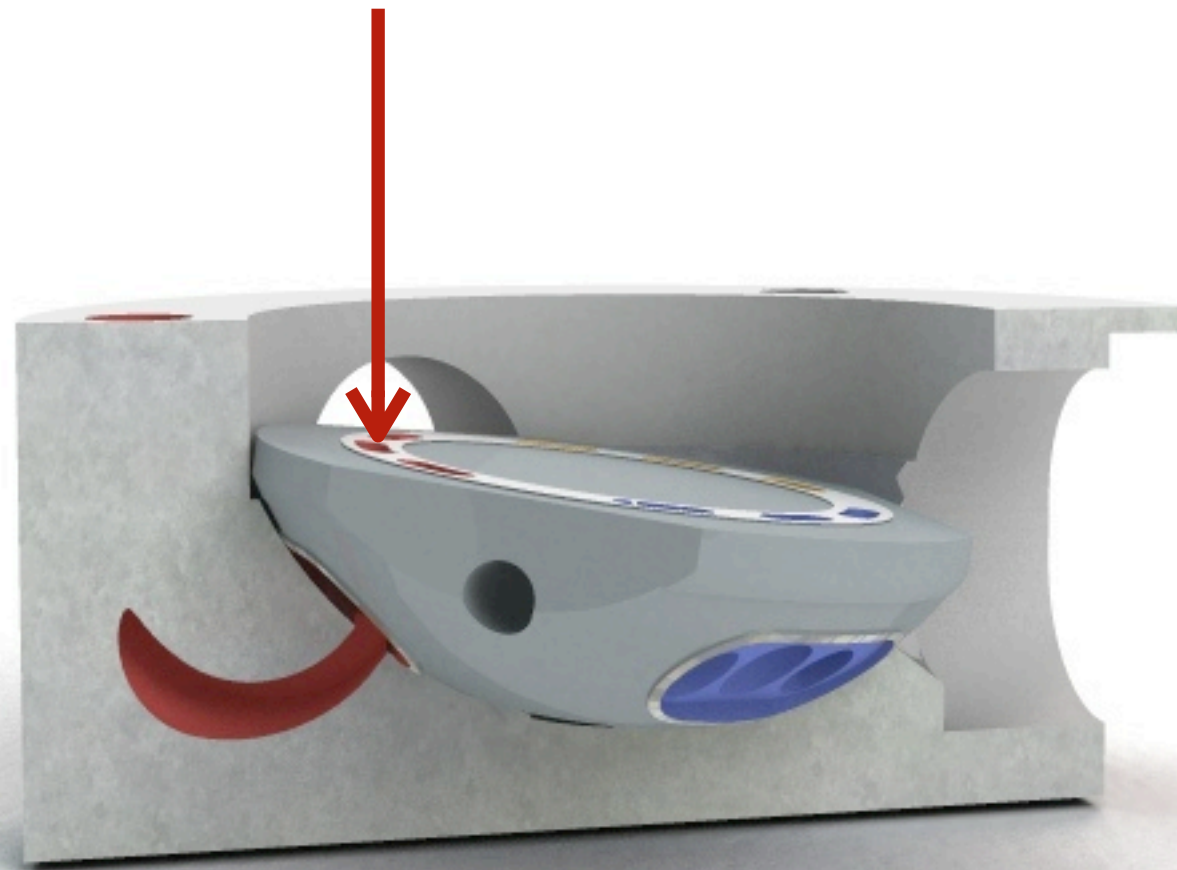




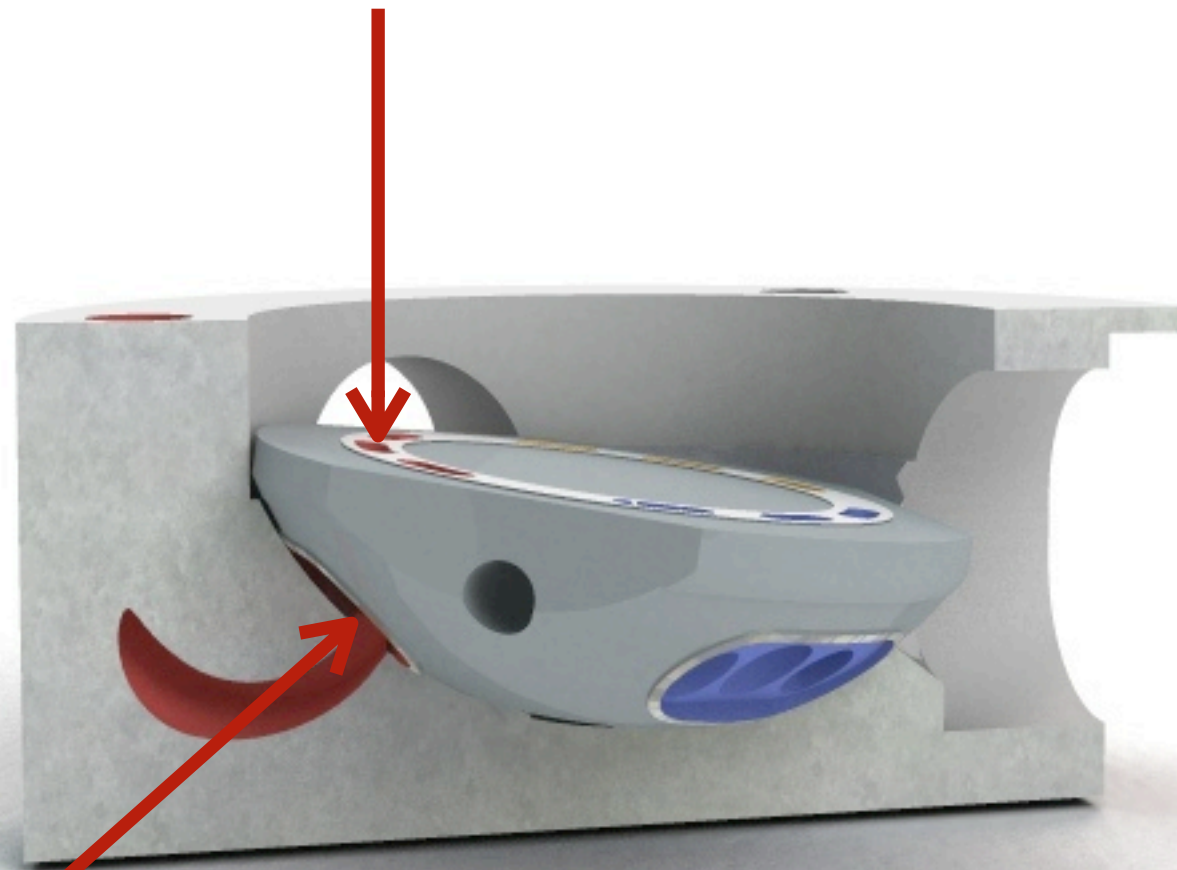




hydrostatic force
from one kidney

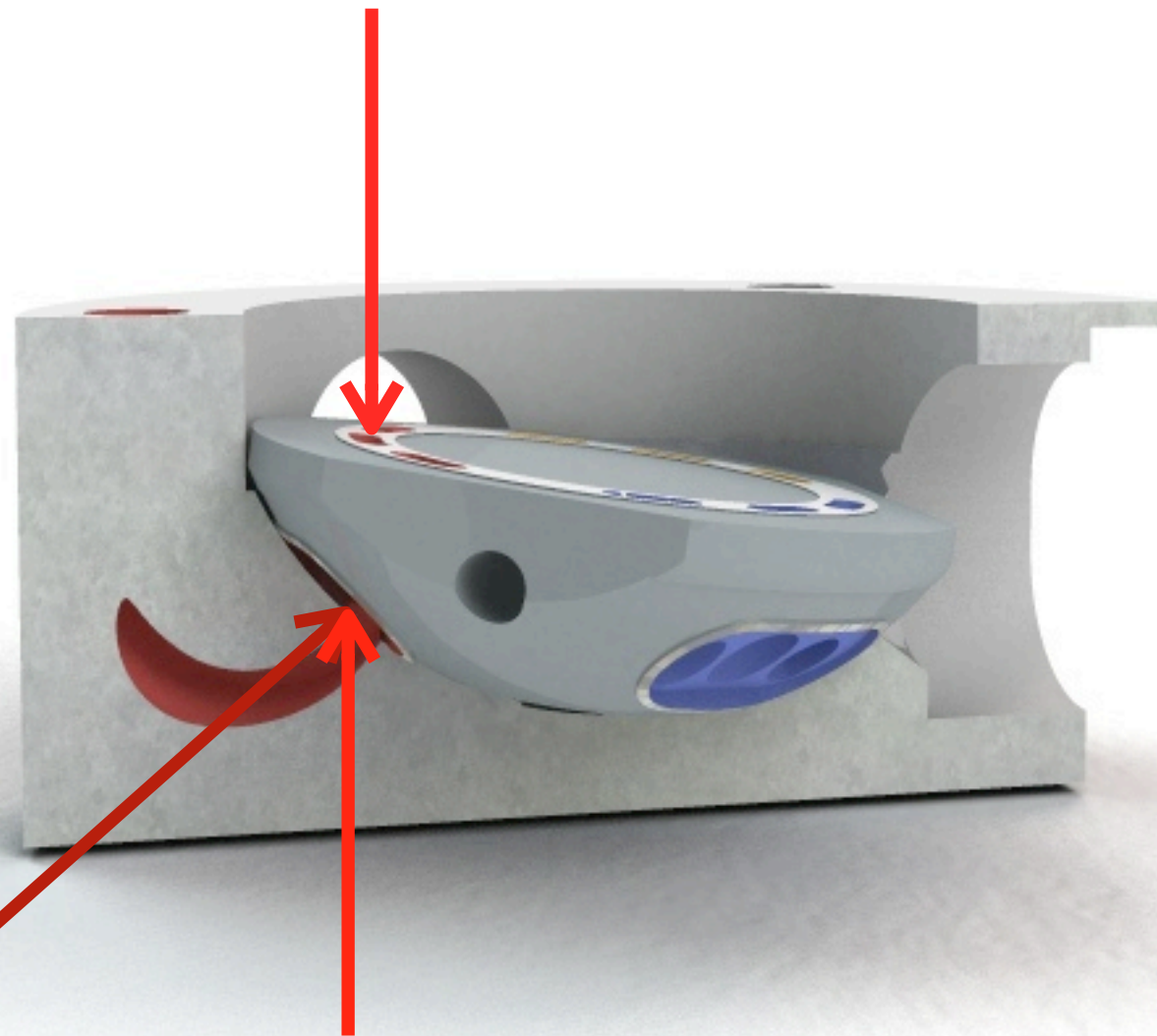


hydrostatic force
from one kidney



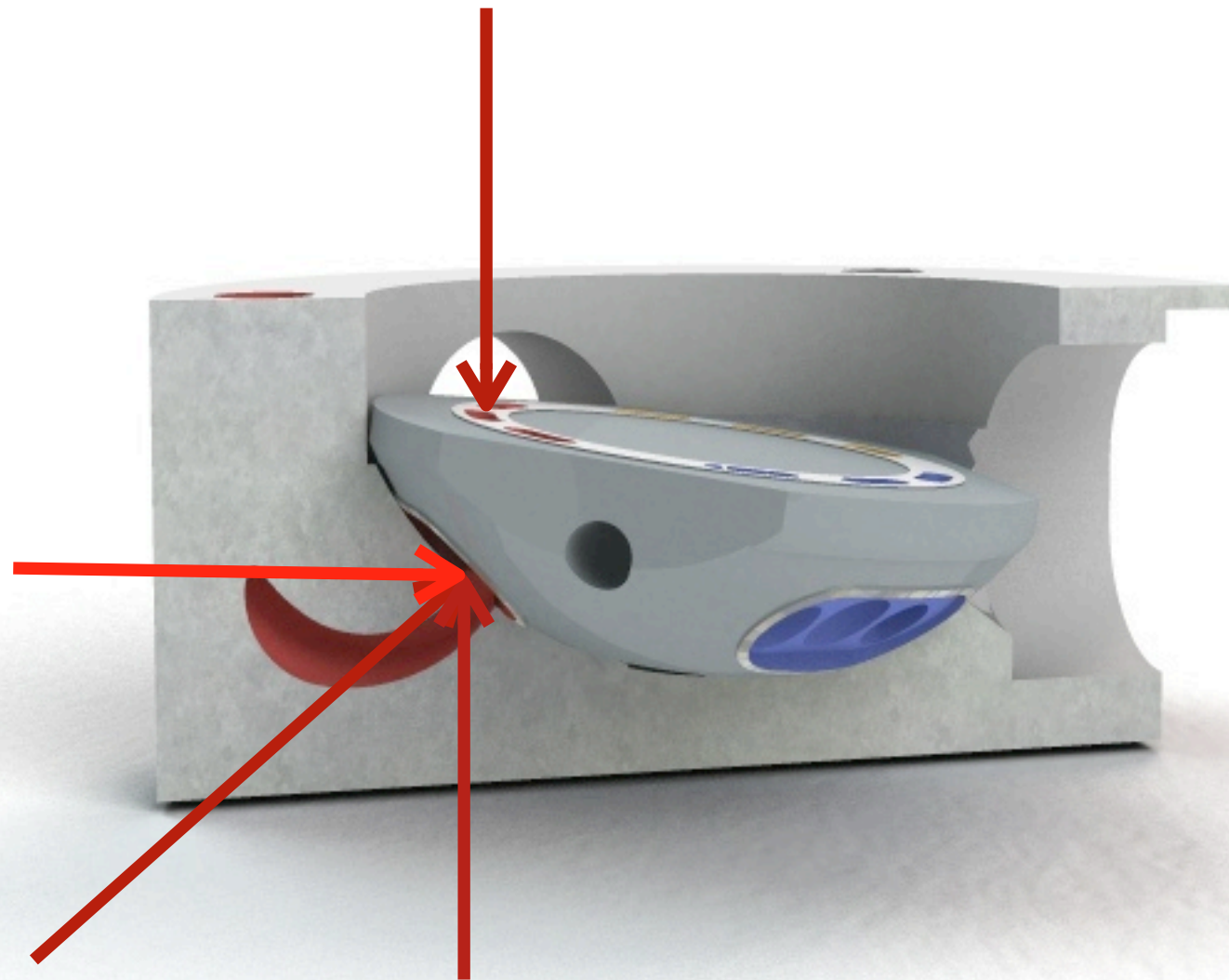
hydrostatic force
from one back port

hydrostatic force
from one kidney

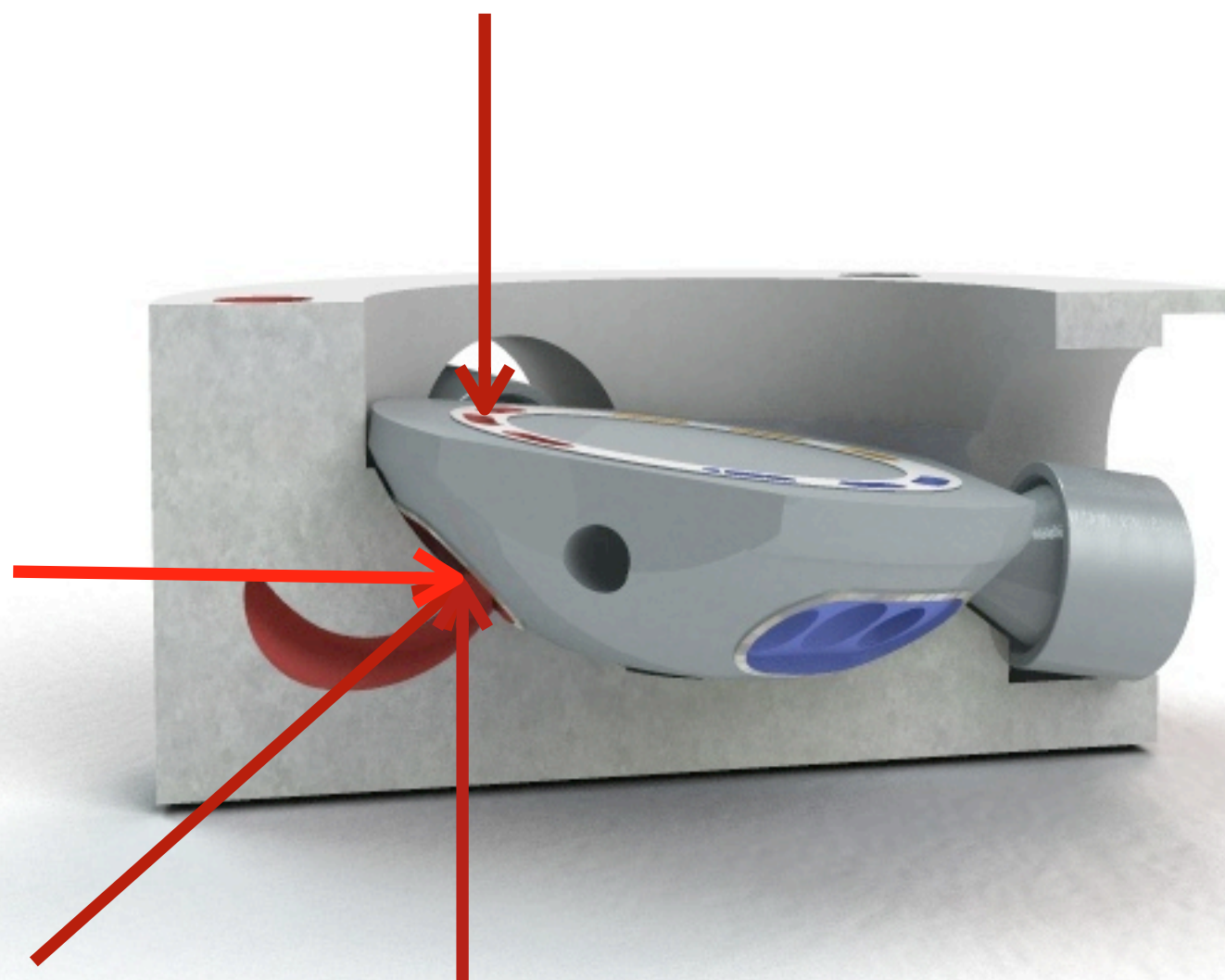


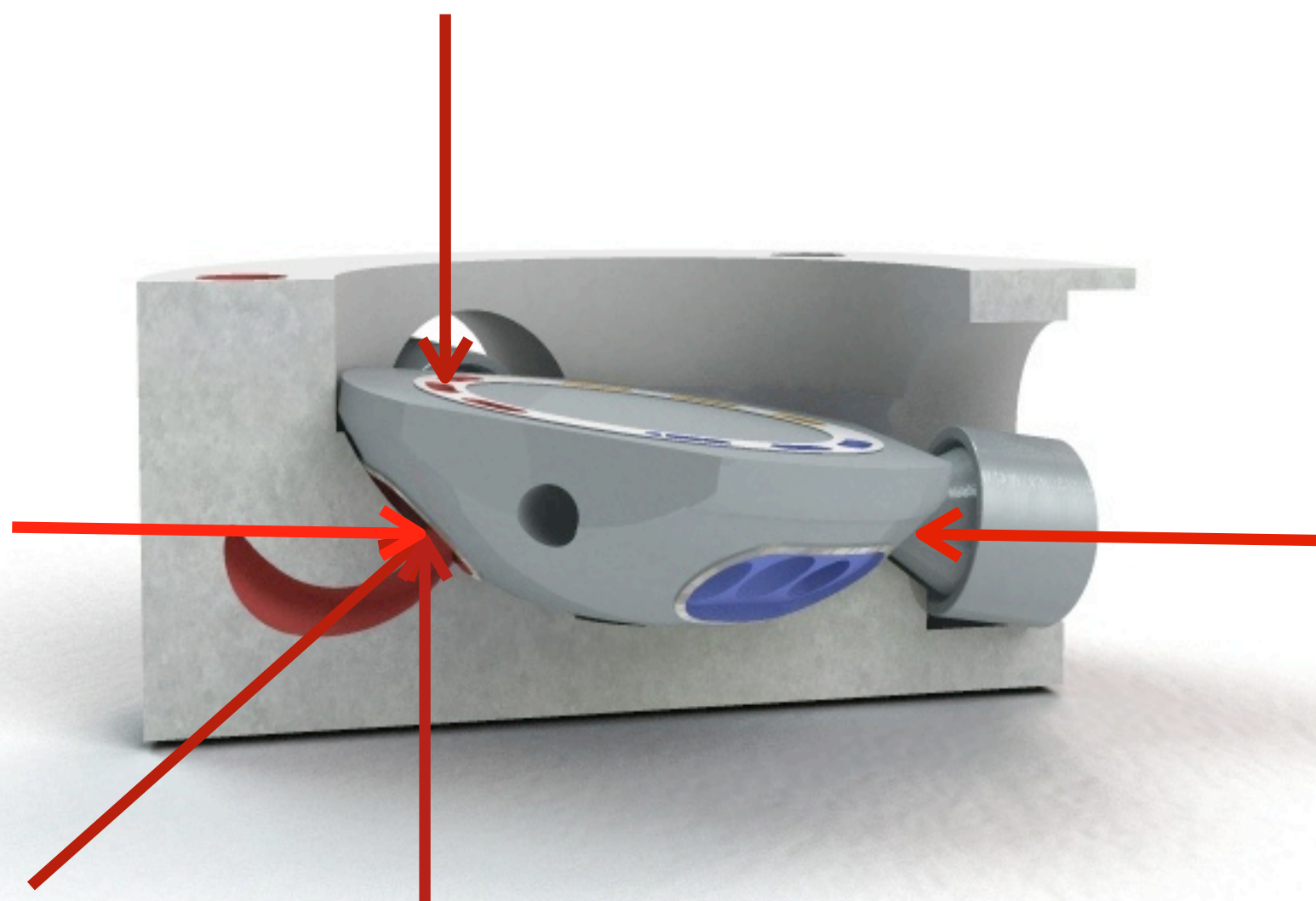
hydrostatic force
from one back port

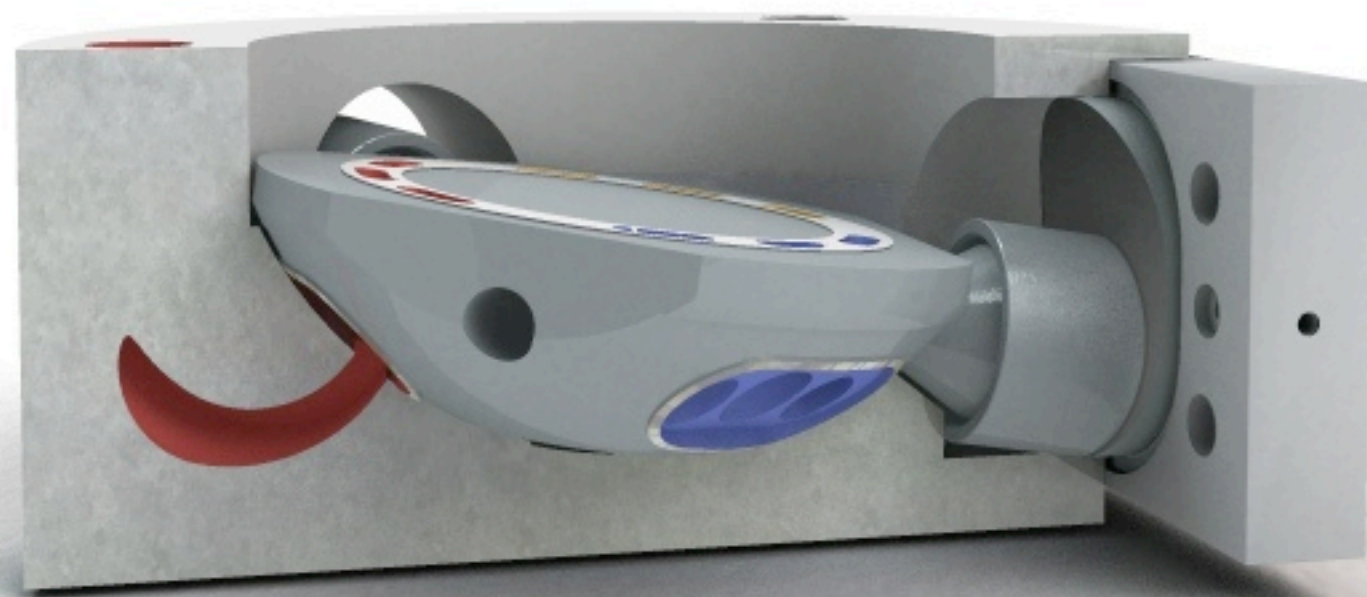
hydrostatic force
from one kidney



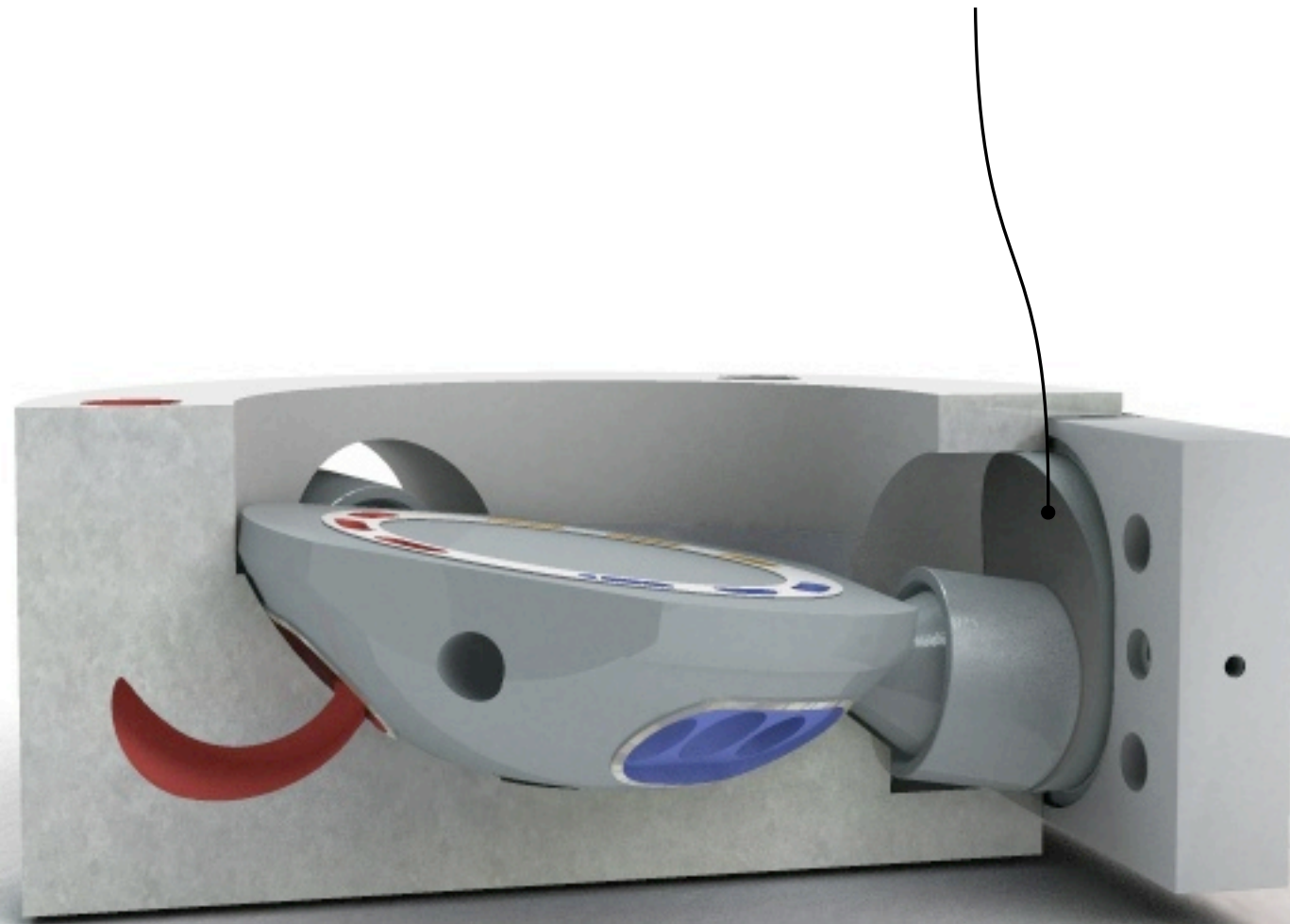
hydrostatic force
from one back port

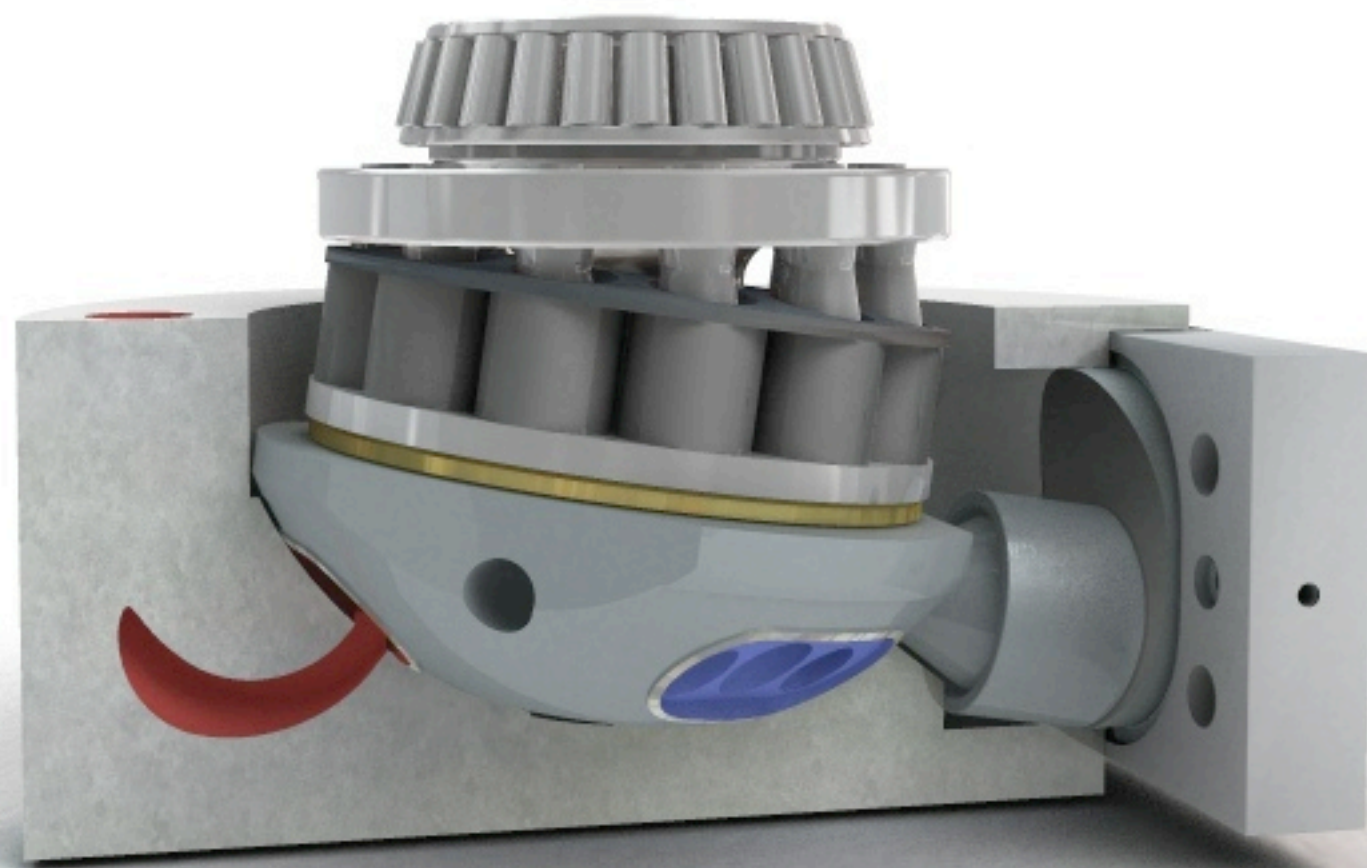




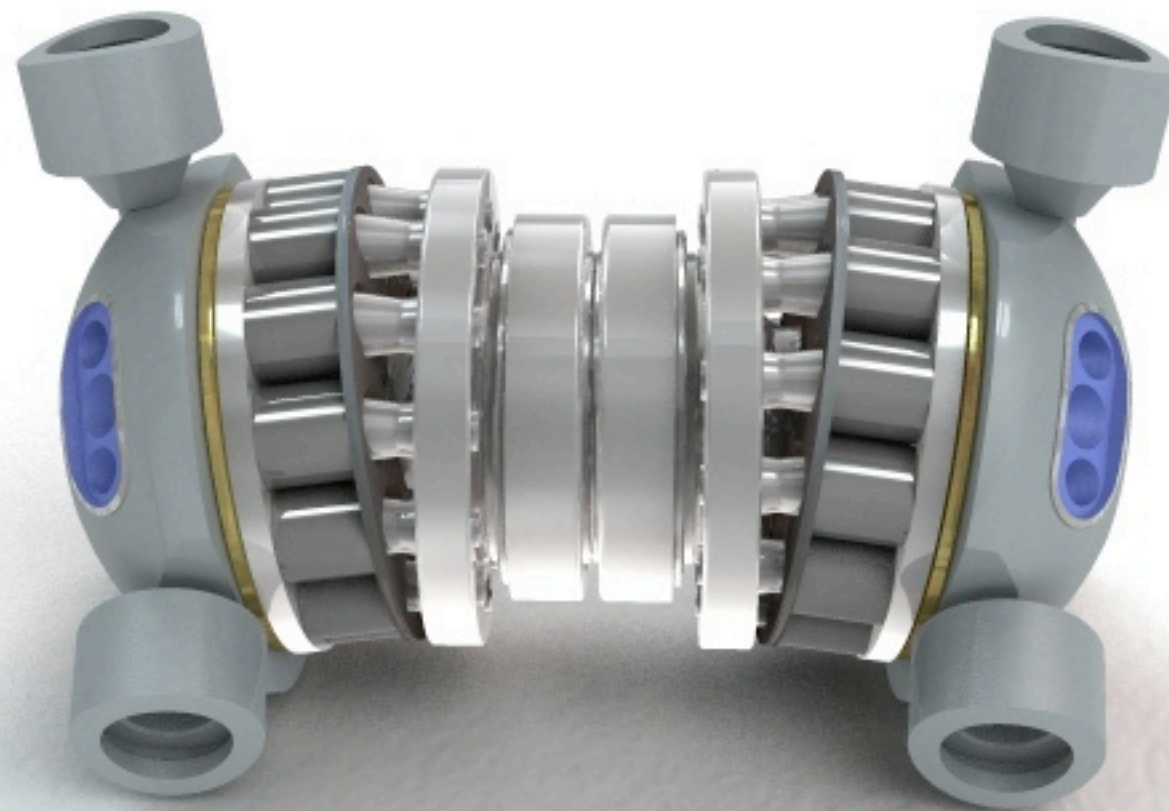


cylindrical bearing surface



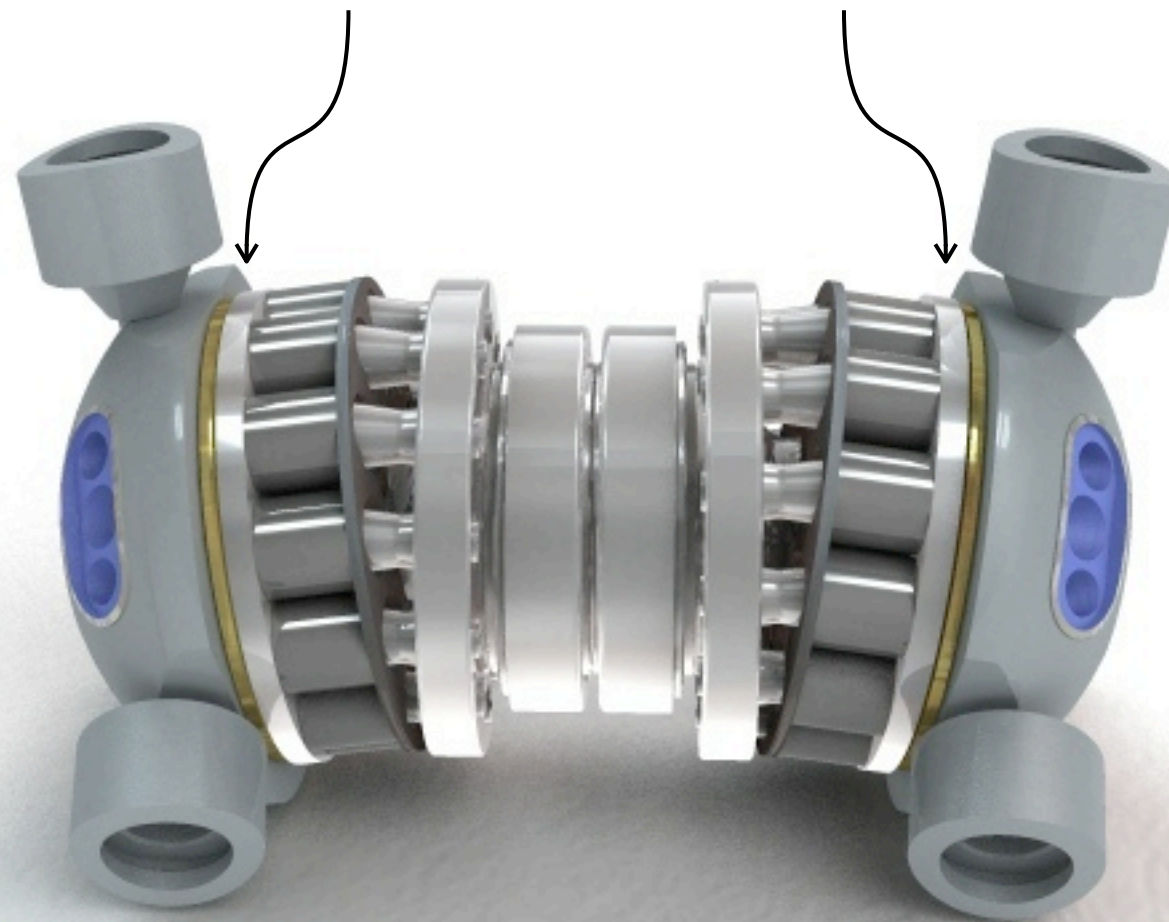


the Oiler transformer

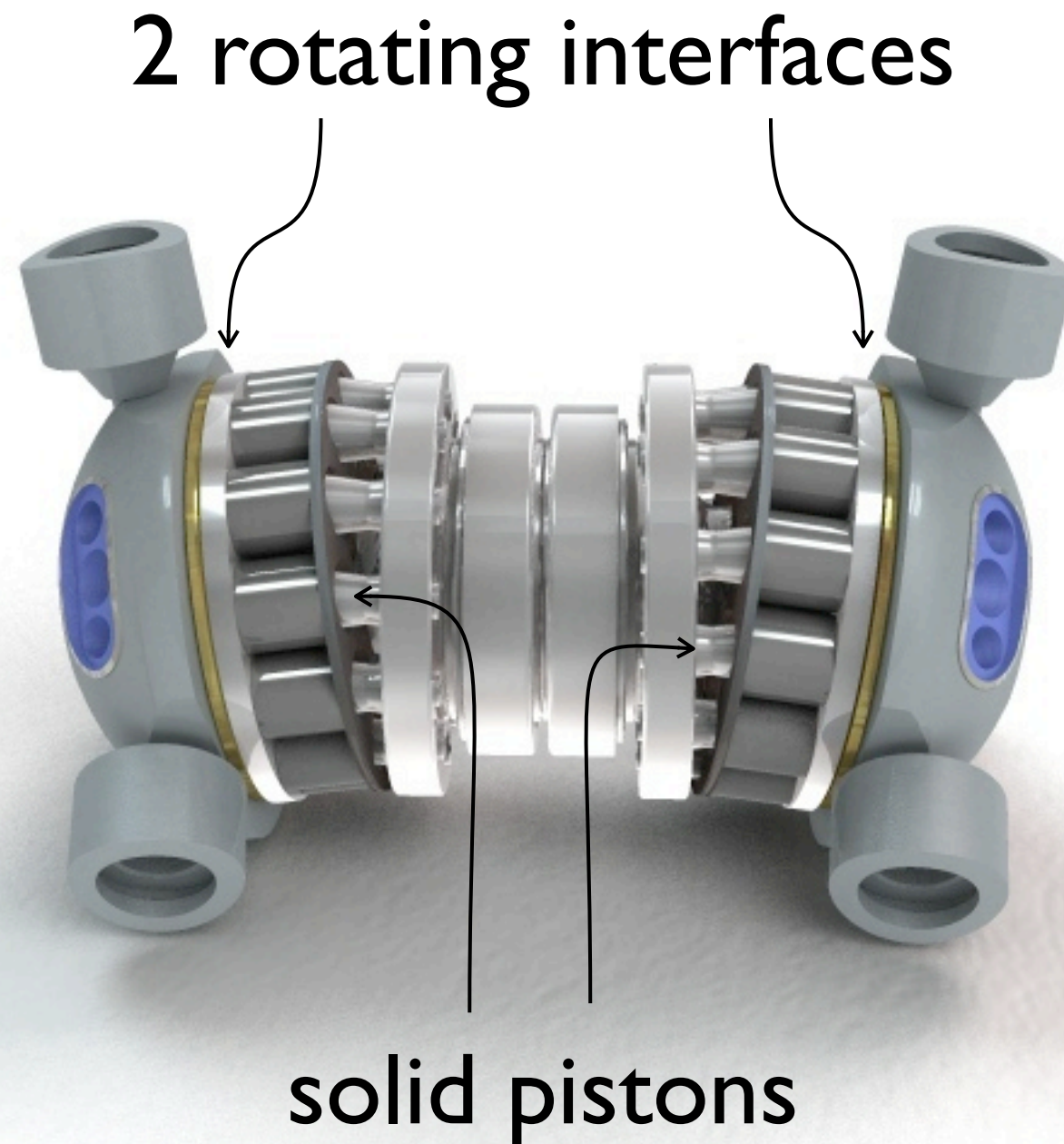


the Oiler transformer

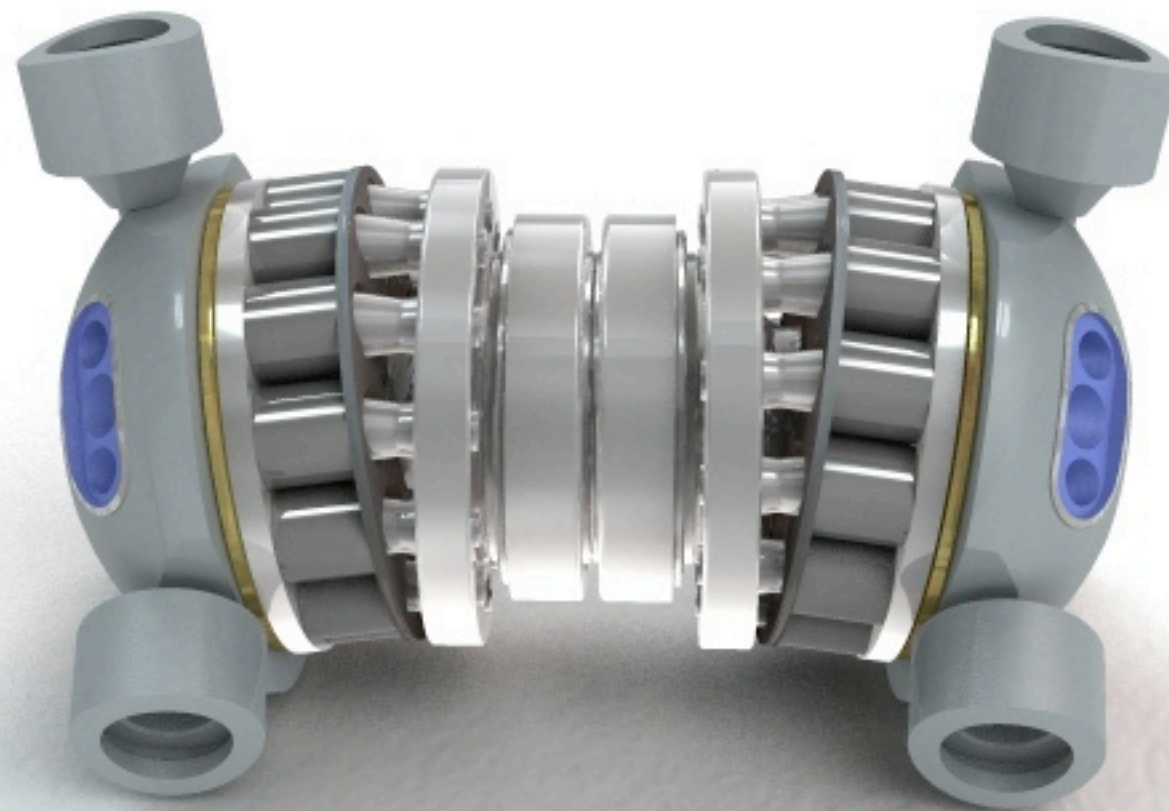
2 rotating interfaces



the Oiler transformer

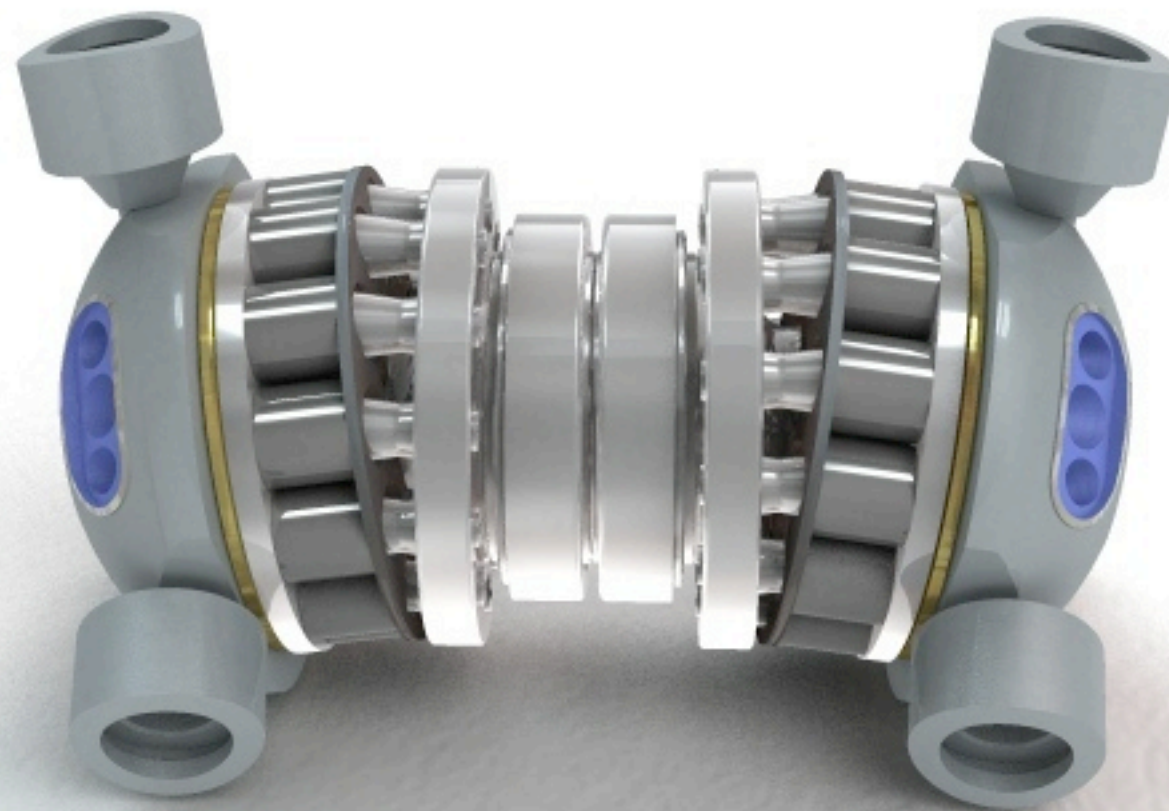


Development target



Development target

average cycle efficiency:
 $87\% \Rightarrow 93\%$



the importance
of a high efficiency

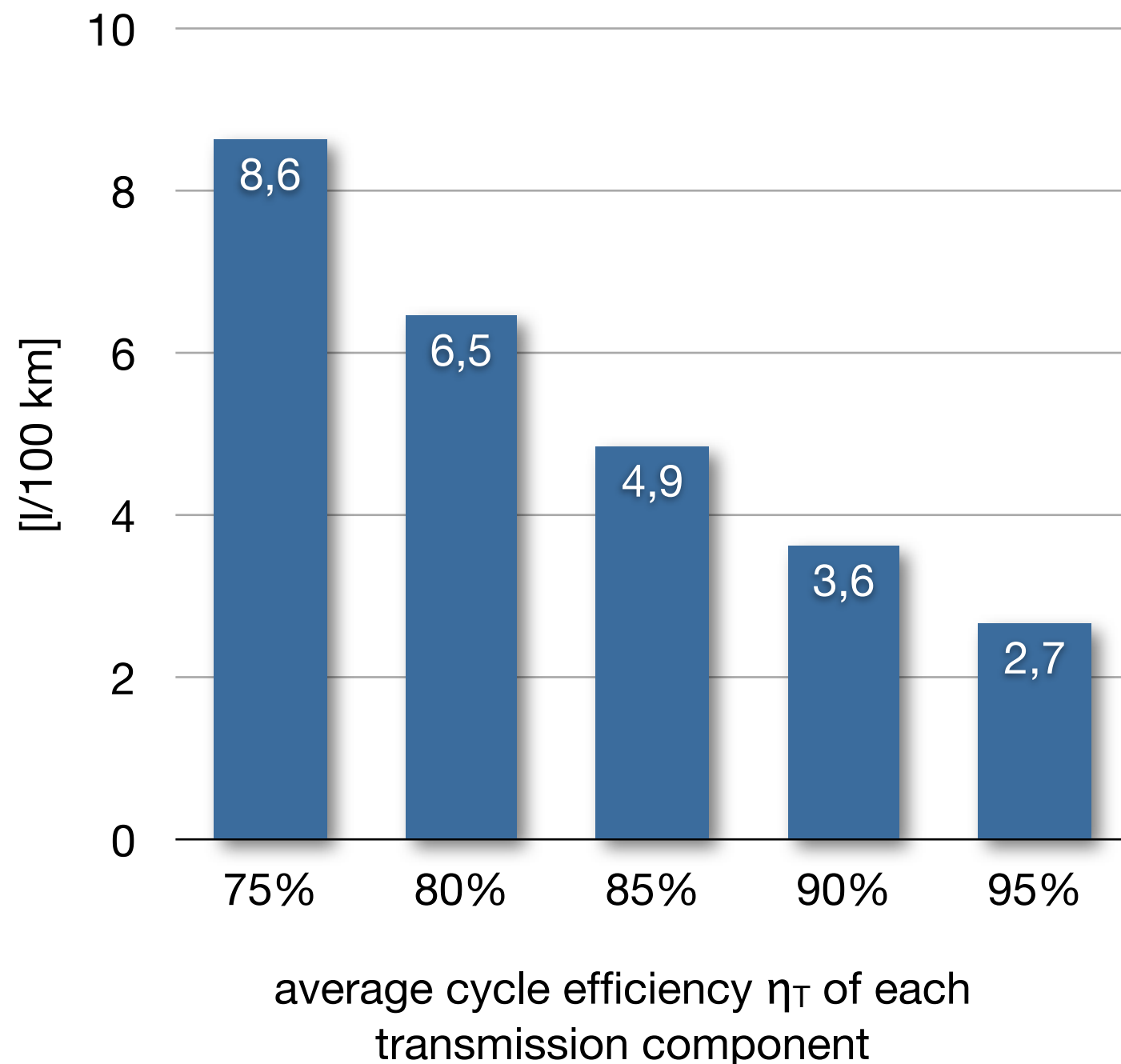
influence efficiency transmission components

series hybrid fuel consumption NEDC
($E_{\text{kin}} = 397 \text{ Wh}$, $E_{\text{drag}} = 767 \text{ Wh}$, $\eta_{\text{ICE}} = 37\%$)

average cycle efficiency η_T of each
transmission component

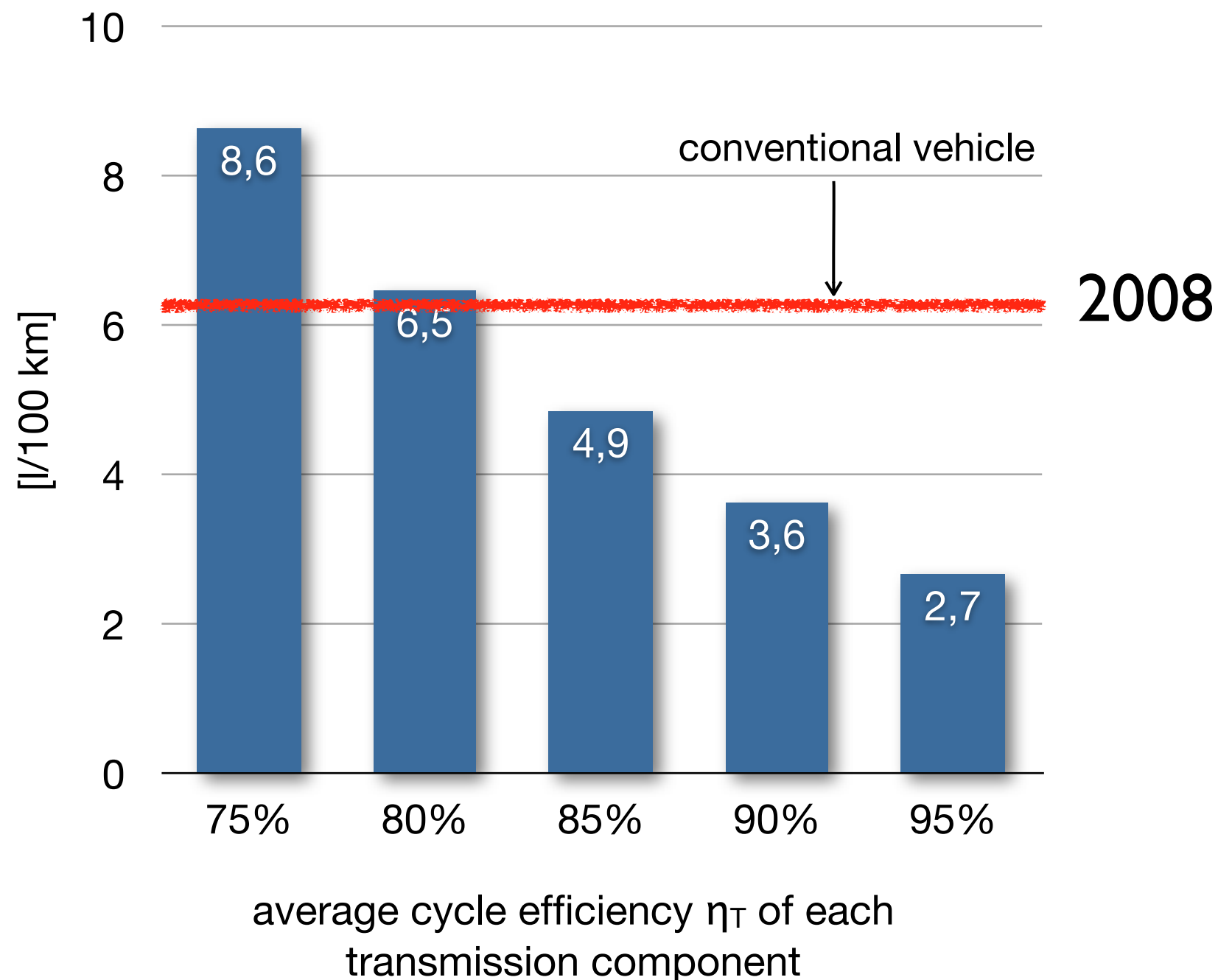
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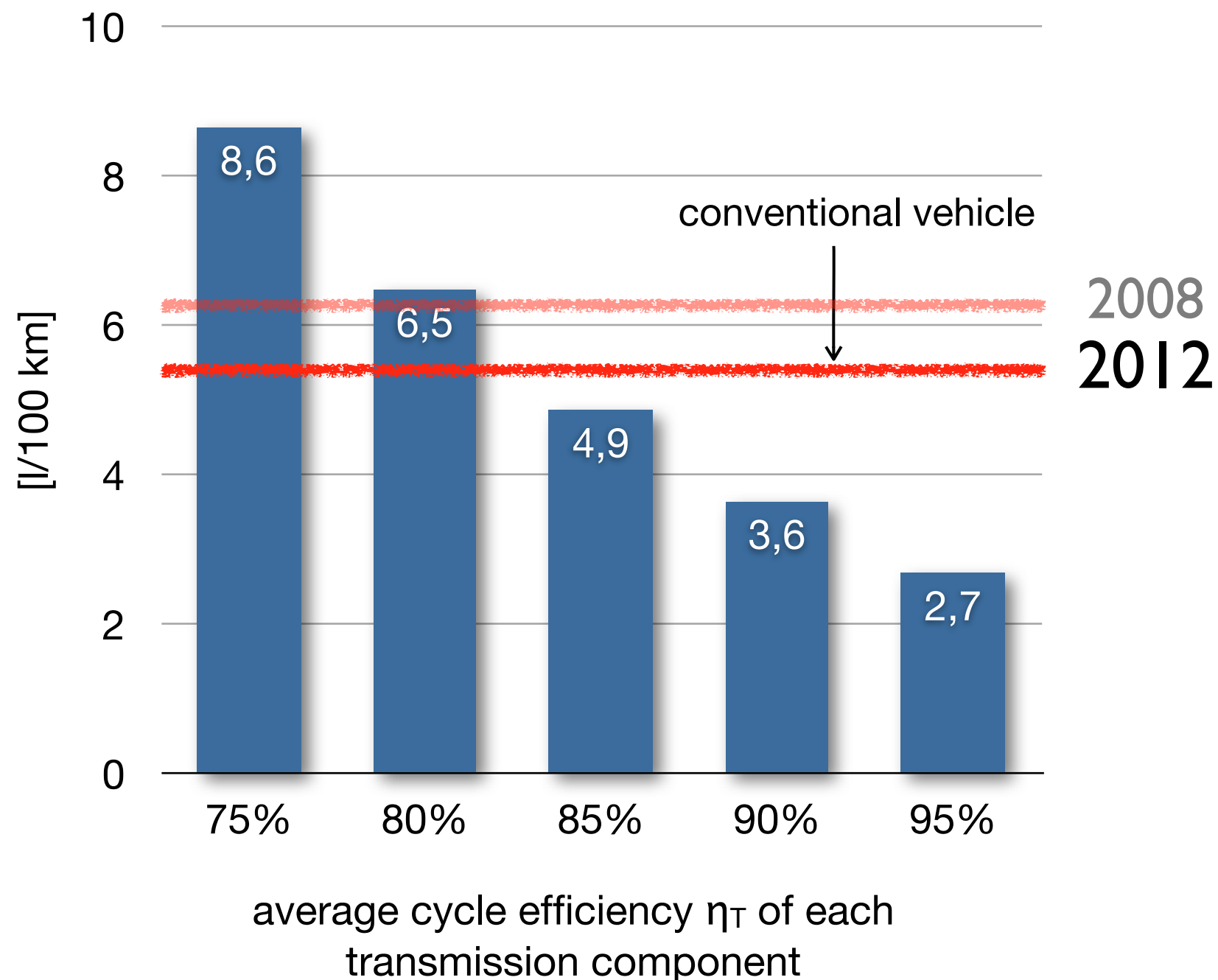
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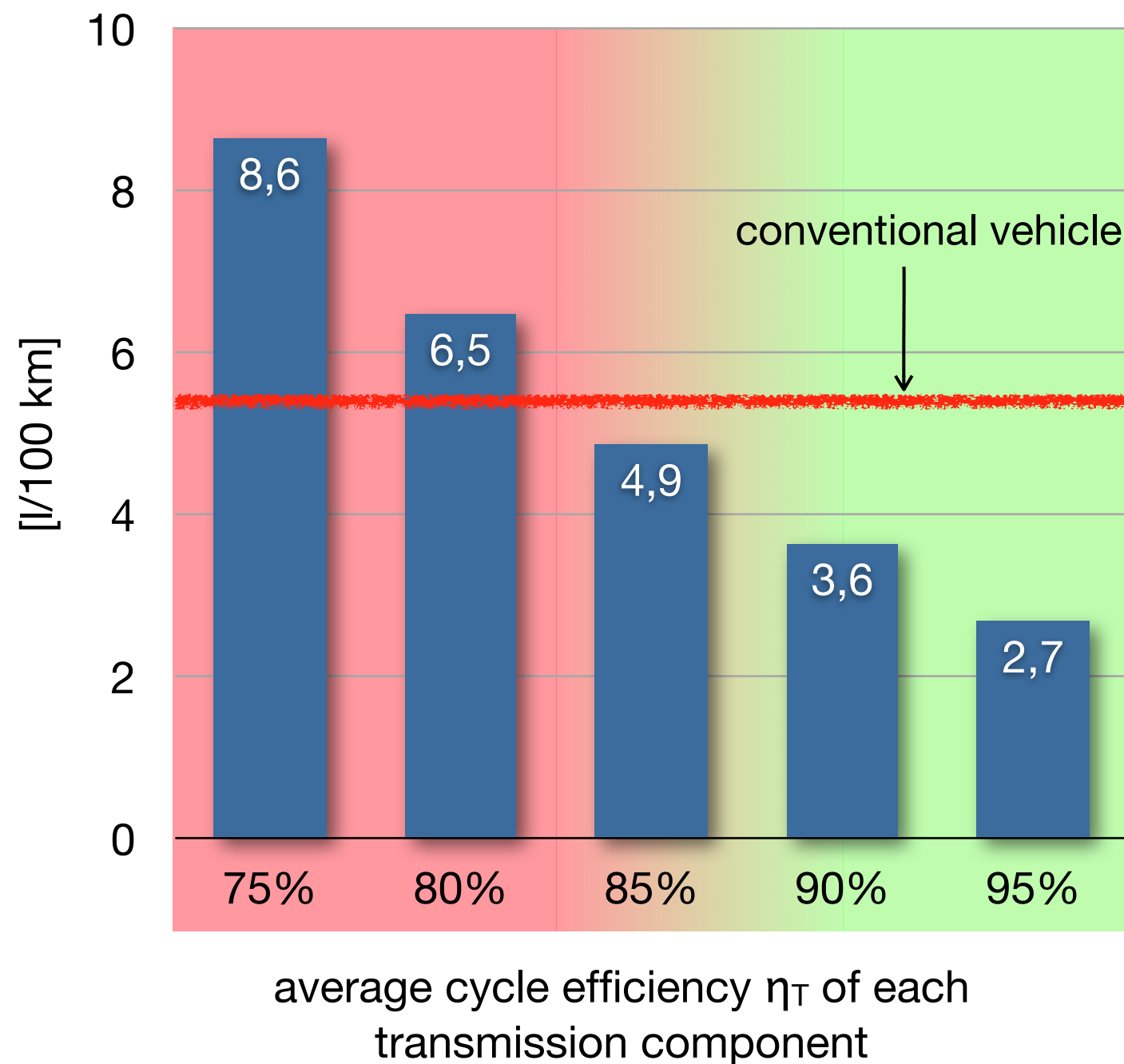
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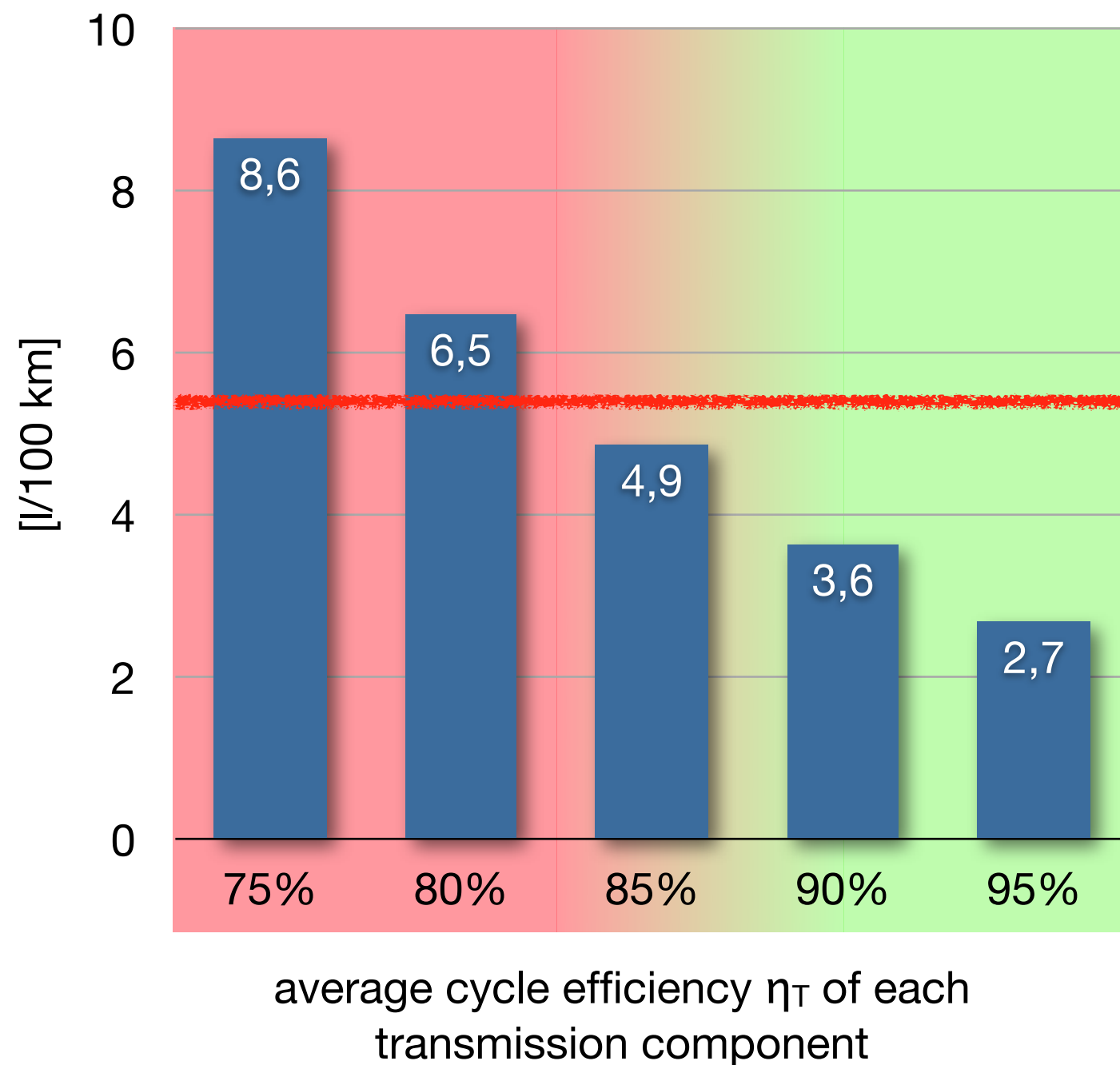


influence efficiency transmission components

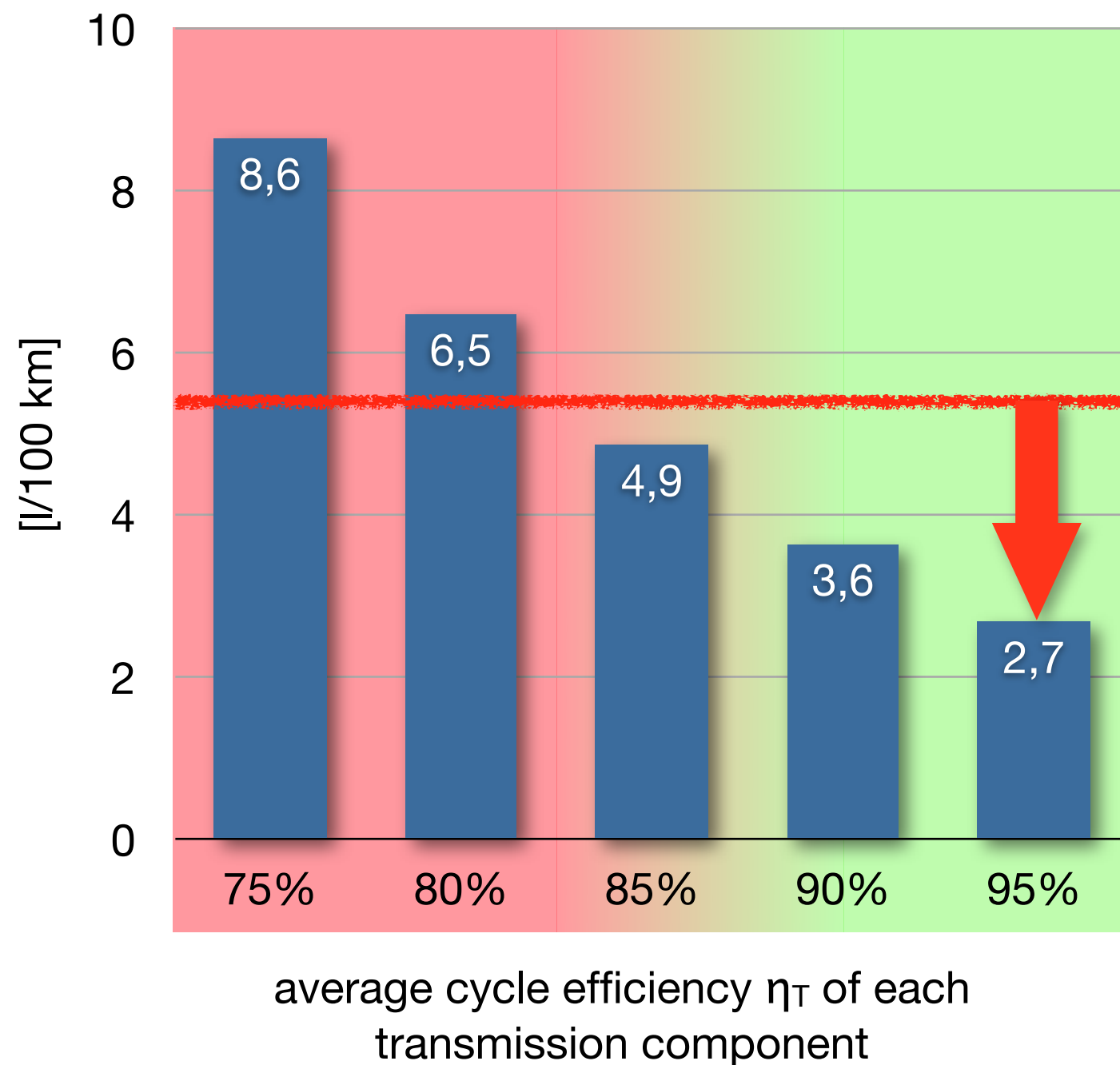
series hybrid fuel consumption NEDC
($E_{\text{kin}} = 397 \text{ Wh}$, $E_{\text{drag}} = 767 \text{ Wh}$, $\eta_{\text{ICE}} = 37\%$)



series hybrid systems:

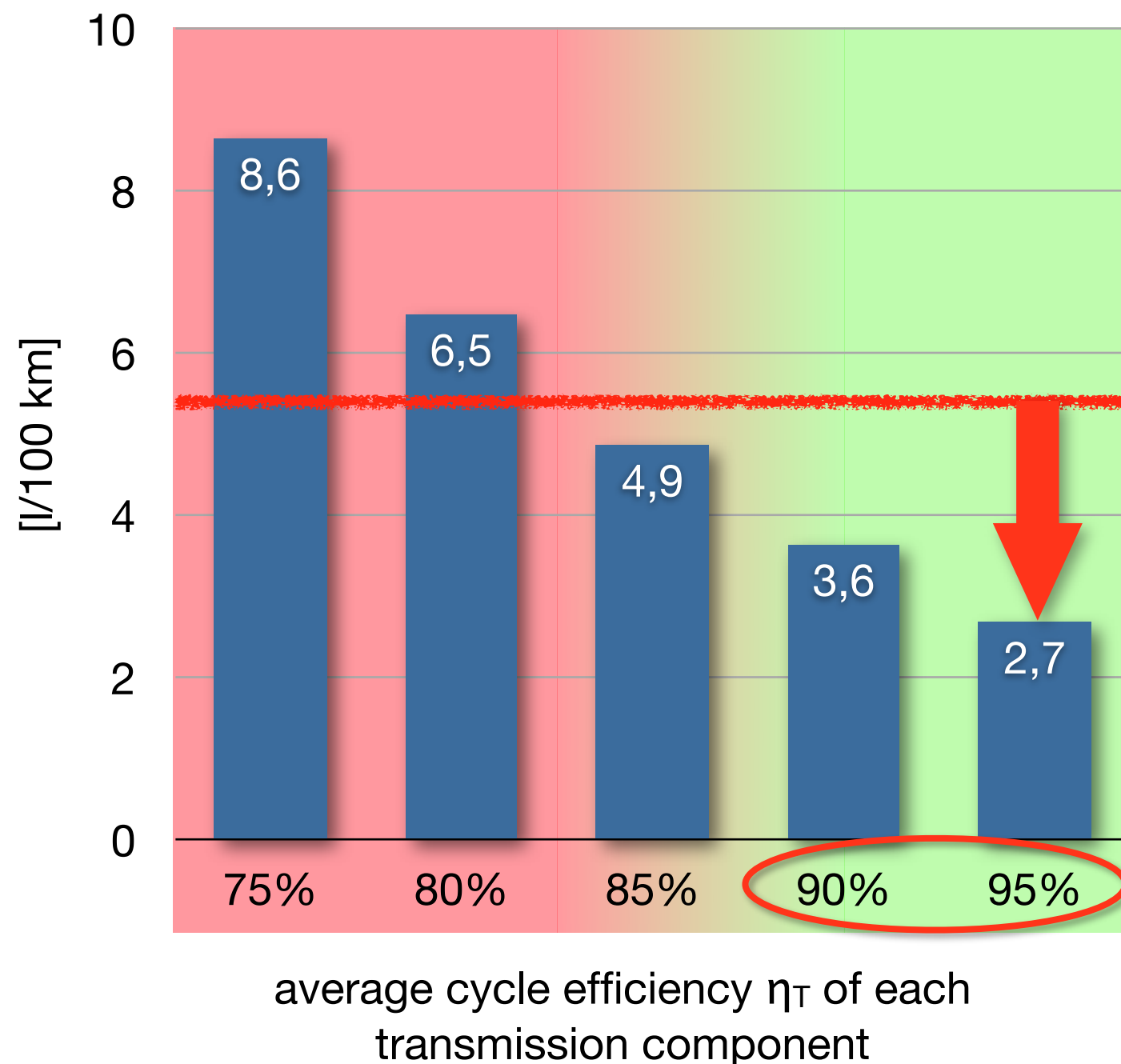


series hybrid systems:



❖ potential strong reduction of fuel consumption

series hybrid systems:



- ❖ potential strong reduction of fuel consumption
- ❖ require a **high average cycle efficiency** of the transmission components

conclusions

lessons learned

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- ❖ **stop** making demonstrators on the basis of current hydraulic components

lessons learned

- ❖ **stop** making demonstrators on the basis of current hydraulic components
- ❖ develop efficient, quiet, dynamic, compact and cost-effective components

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