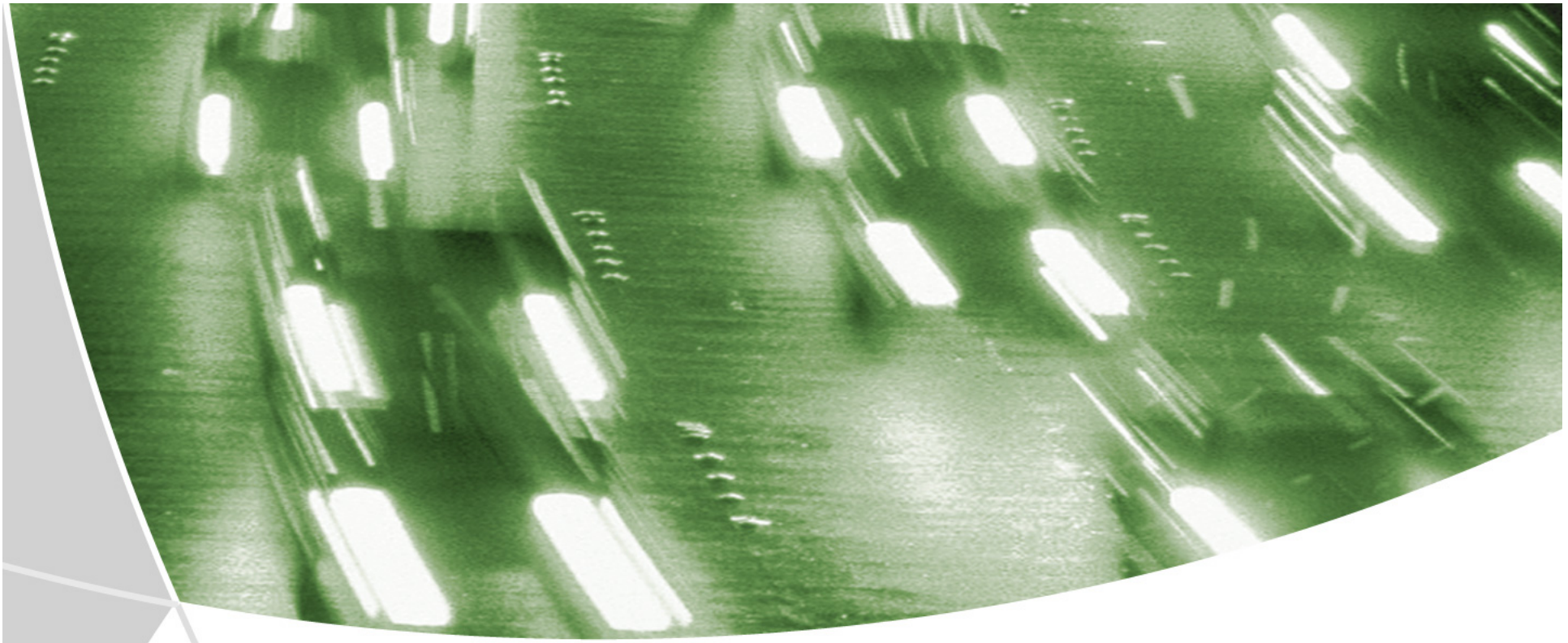

Electric Wheel-Hub-Drive for Aircraft Application

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Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

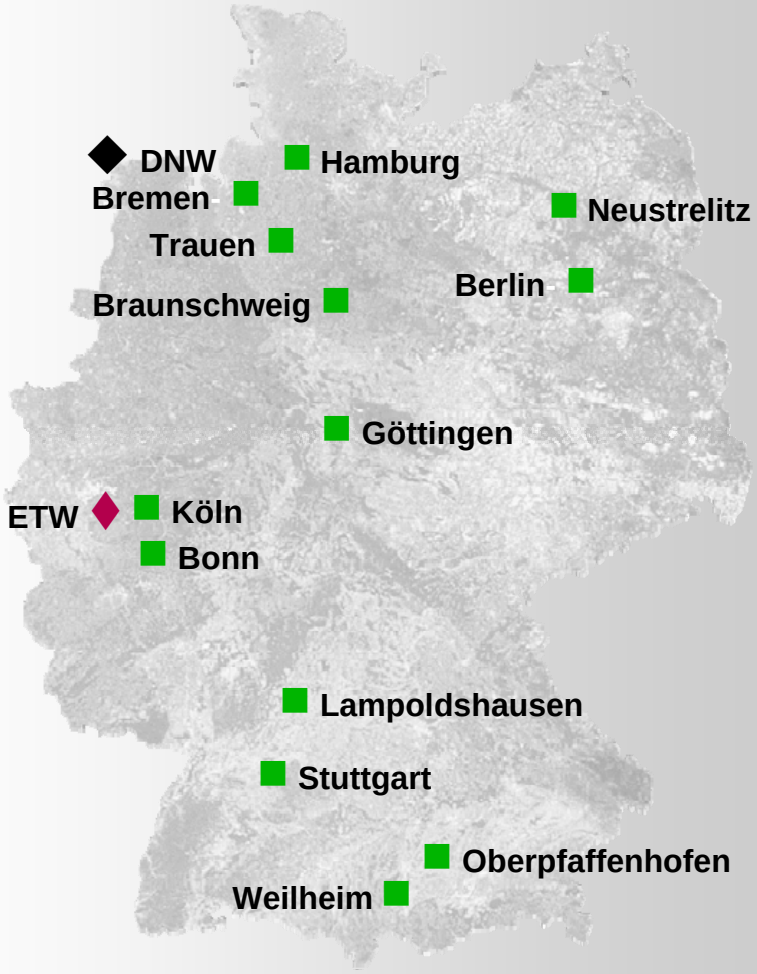
Introduction
DLR – German Aerospace Center

- Research center
  - Aeronautics
  - Space
  - Energy
  - Transport

- Space agency
- Project management agency

Introduction
DLR – Sites and Employees

- 6,400 staff working in 29 research institutes and facilities at
  - 13 sites
- Offices in Brussels, Paris and Washington
- Partner of
  - European Transsonic Wind Tunnel (ETW)
  - German Dutch Wind Tunnels (DNW)



Electric Wheel-Hub-Drive for Aircraft Application
Content

- Introduction

- Requirements for passenger aircraft autonomous taxiing

- Interfaces to the nose landing gear

- Design of an electric wheel-hub-drive with a high degree of integration

- Test bench results

Electric Wheel-Hub-Drive for Aircraft Application

Requirements for Passenger Aircraft Autonomous Taxiing

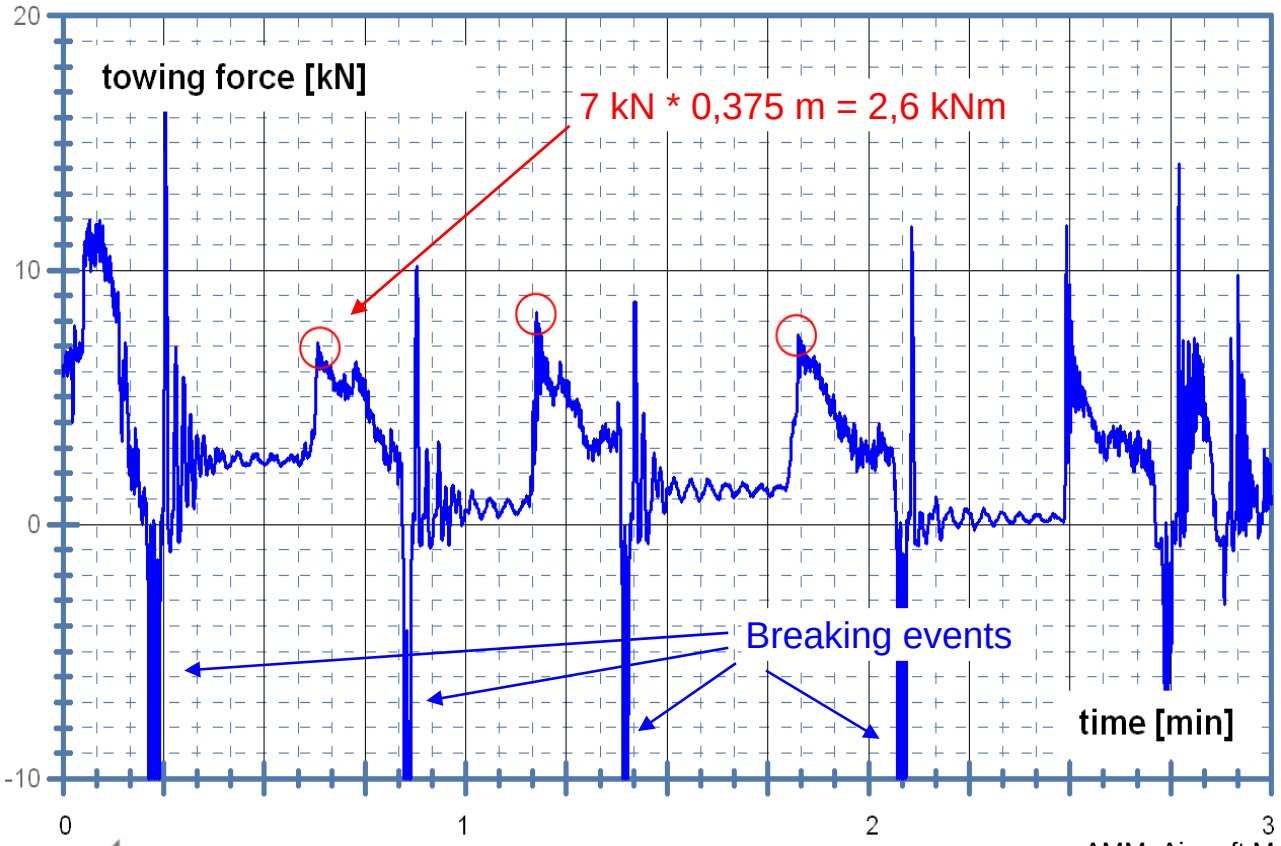
- Task: Autonomous taxiing of a passenger aircraft A320
- Driving conditions: TOW 50 tons with 25 km/h
- Maximun power of 50 kW

To be solved by a drive within the NLG:
- Electric machine integrated in the rim of the NLG
- Three switchable gear ratios
- Fed by a fuel cell system

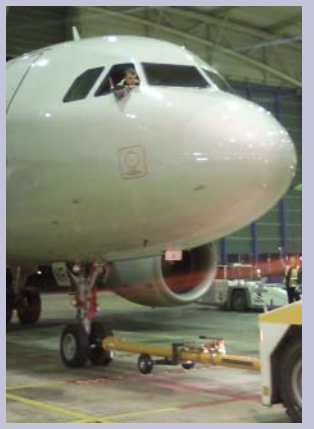
TOW: Take Off Weight, NLG: Nose Leg Gear

Electric Wheel-Hub-Drive for Aircraft Application, Boundary Conditions

- AMM: Towing force = 1,5% of TOW = 7,4 kN
  Break away force = 6 % of TOW = 29 kN

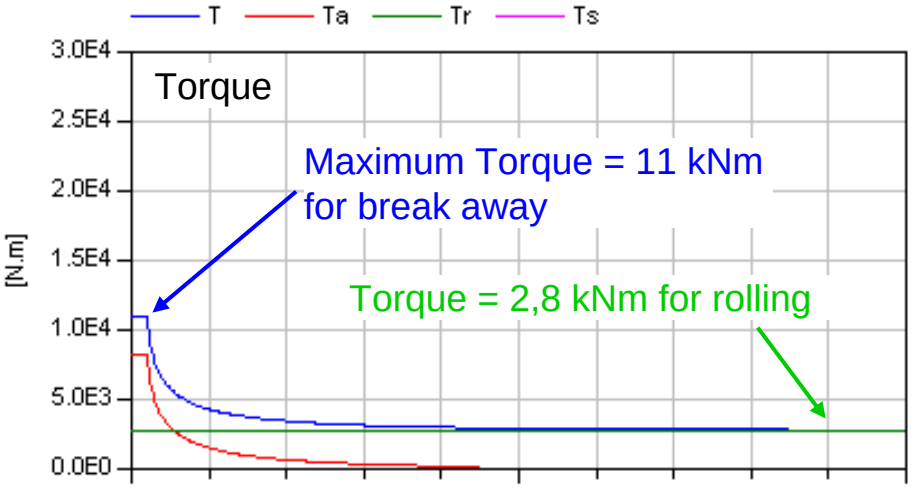


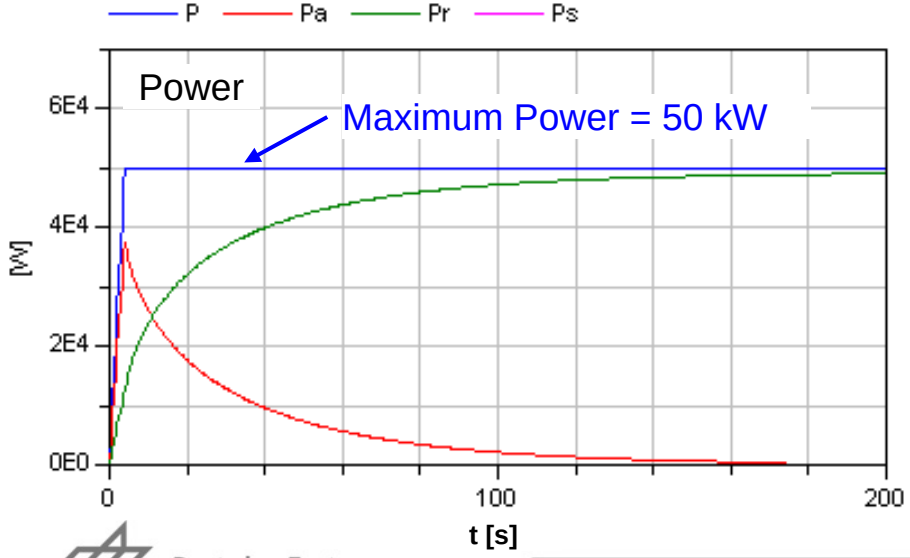
- Measured towing force < 7 kN
- Measured break away force = 7 kN (2,6 kNm)



AMM: Aircraft Maintenance Manual, TOW: Take Off Weight

Electric Wheel-Hub-Drive for Aircraft Application
Driving Conditions



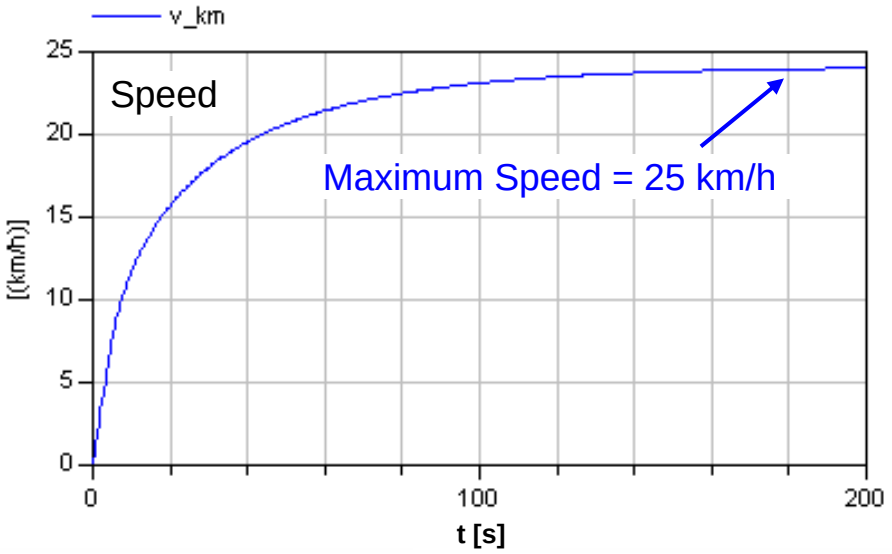


Variables:

T:	**Torque overall**	
Ta:	**Torque for acceleration**	
Tr:	**Torqur for rolling**	
P:	**Power overall**	
Pa:	**Power for acceleration**	
Pr:	**Power for rolling**	
v_km:	**velocity in km/h**	

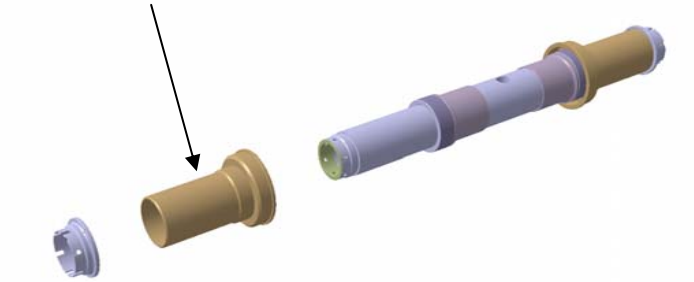
Parameters:

Mass: 50 t
Wheel load: 5 t
Friction coefficient rolling: 0,015
Friction coefficient adhesion: 0,6
Power supply: 50 kW
slope = 0 %

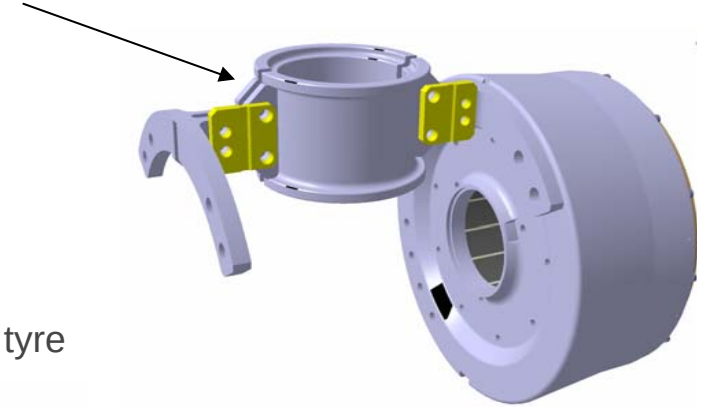


Electric Wheel-Hub-Drive for Aircraft Application, Interfaces to the Nose Leg Gear

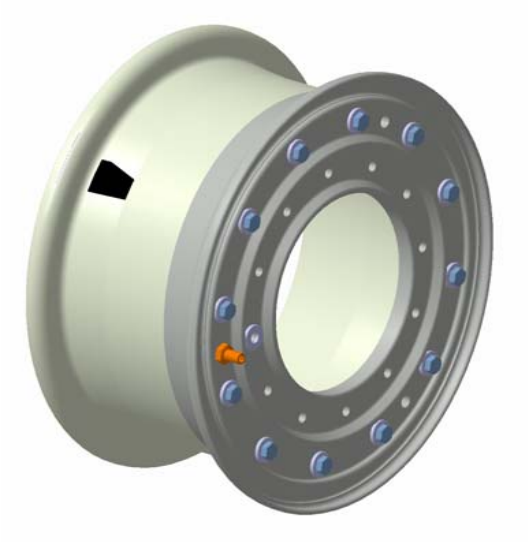
Sleeve as the mechanical interface to the axle



Torque link as the mechanical interface to the strut



Rim as the interface to the tyre



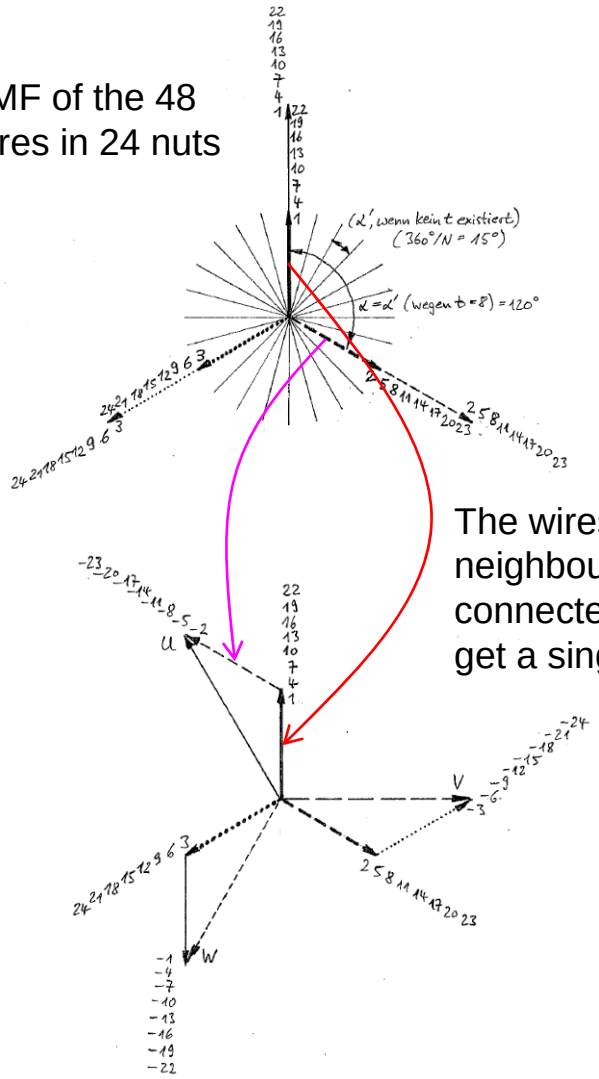
Original design of the NLG

Axle and strut imitation

NLG: Nose Leg Gear

Design of the Electric Machine

EMF of the 48 wires in 24 nuts



The wires of two neighboured nuts are connected in series to get a single tooth coil

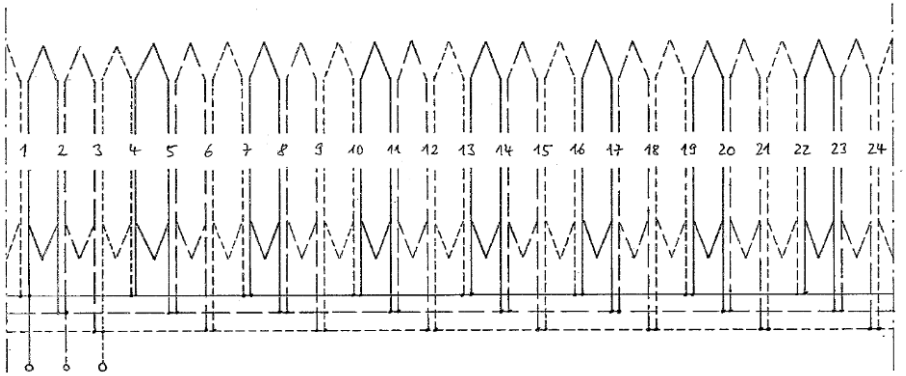
m = 3 phases

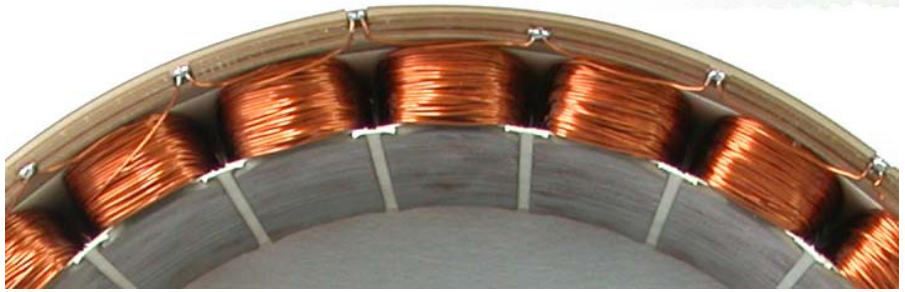
p = 8 pole pairs

N = 24 single teeth

→ 8 delta connected phase systems in parallel

→ winded in one step

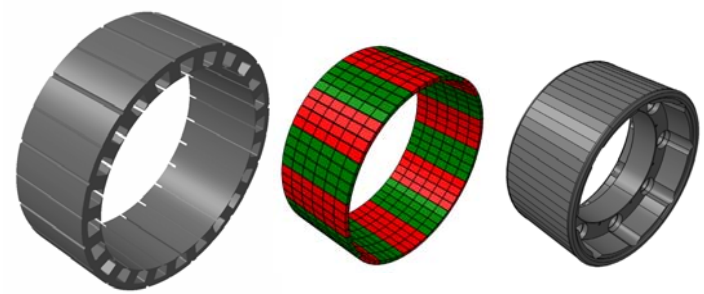


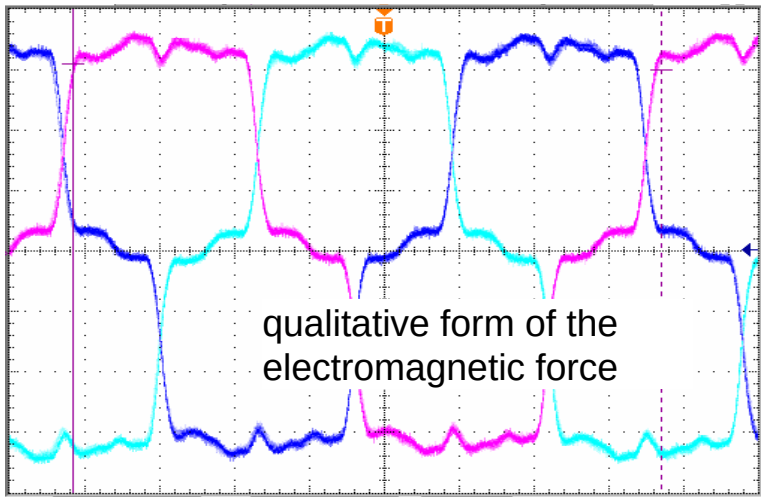


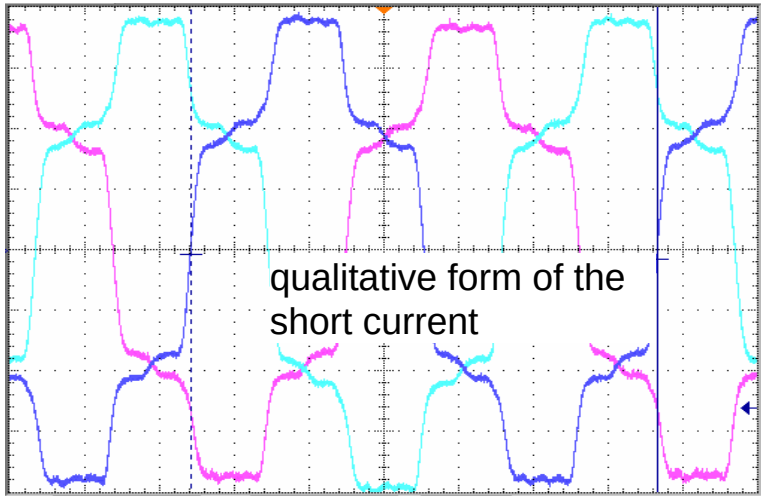
EMF: Electromagnetic Force

Design of the Electric Machine

- 120 ° rectangular form of EMK
- 120 ° rectangular stair form of short current
- 220 Nm, 2000 1/min at gear ratio 1:1

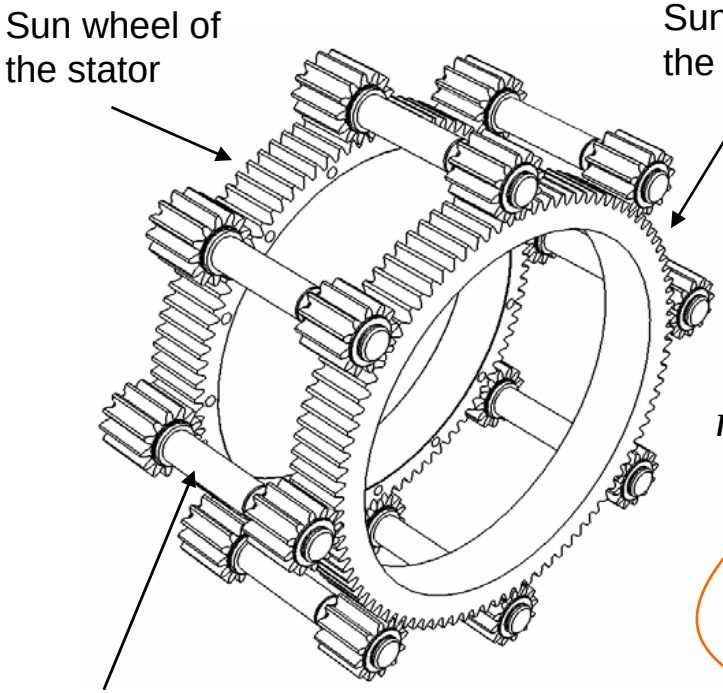






EMF: Electromagnetic Force

Design of the Gear System



220 Nm, 2000 1/min at gear ratio 1:1
- gear ratio 1:1 for landing
- gear ratio 12:1 for taxiing = 2,6 kNm
- free wheel function

$$n_R = -\frac{z_{Pf}}{z_{Sf}} \cdot \frac{z_{Ss}}{z_{Ps}} \cdot n_M + n_M$$

$$= n_M \cdot \left(-\frac{z_{Pf}}{z_{Sf}} \cdot \frac{z_{Ss}}{z_{Ps}} + 1 \right)$$

$$\frac{n_M}{n_R} = \frac{1}{1 - \frac{z_{Pf}}{z_{Sf}} \cdot \frac{z_{Ss}}{z_{Ps}}}$$

$$n_P = \frac{z_{Ss}}{z_{Ps}} \cdot n_M$$

$$n_R = -\frac{z_{Pf}}{z_{Sf}} \cdot n_P$$

(if rotor stands still)

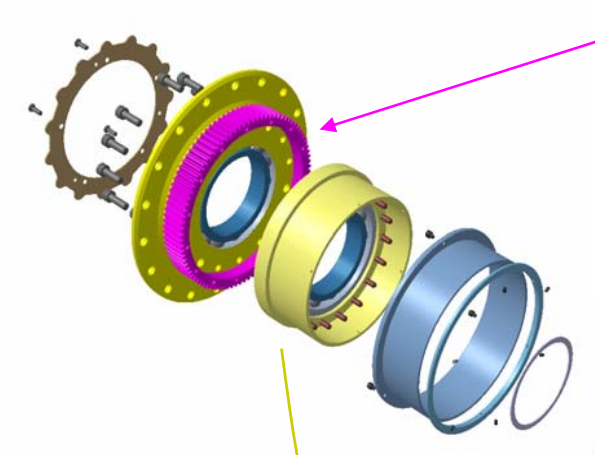
$$n_R = -\frac{z_{Pf}}{z_{Sf}} \cdot n_P + n_M$$

if rotor rotates

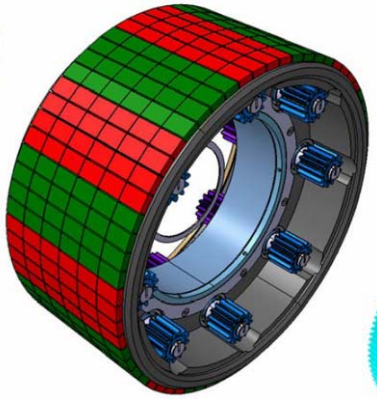
Index: *n* = speed, *z* = number of teeth, *M* = Motor, *S* =Sun, *P* = Planetary, *R* = rim, *s* = side of the stator, *f* = side of the rim

Design of the Gear and Clutch System

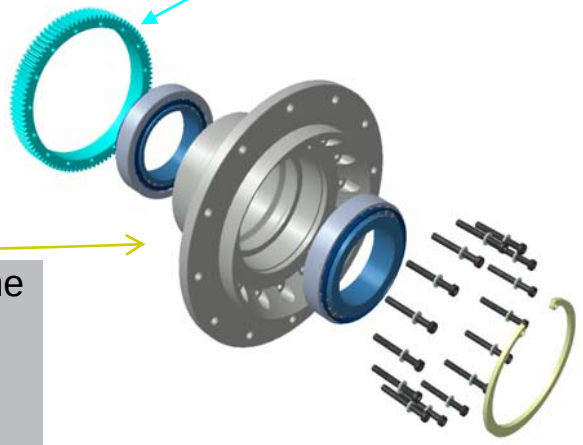
Sun wheel of the stator could be fixed to the stator for **ratio 1:12**



rotor = planetary carrier



sun wheel of the rim

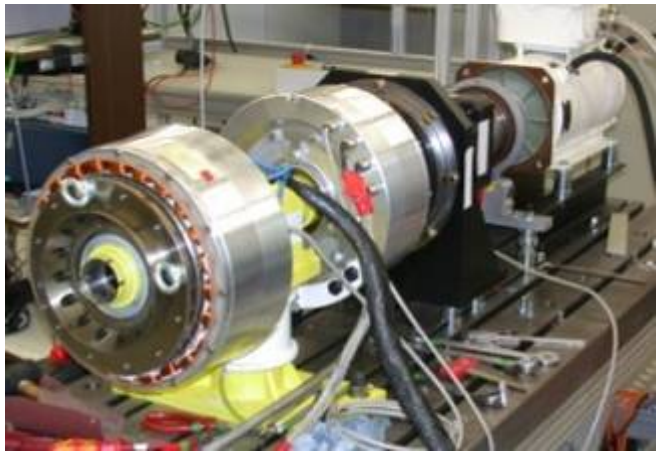


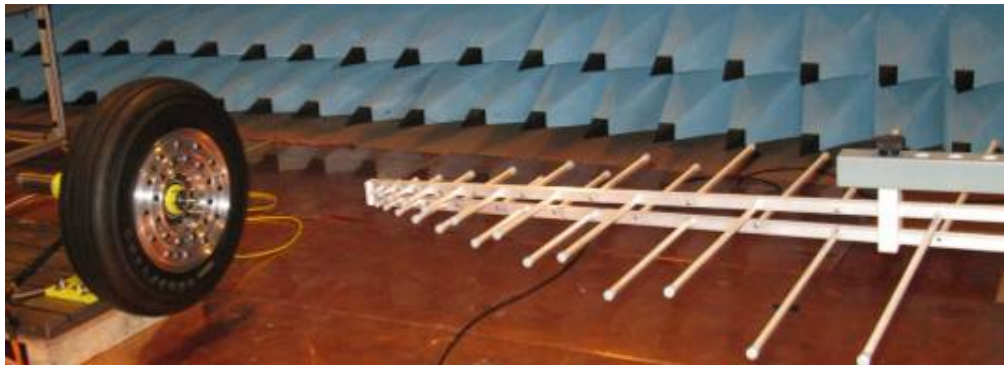
The sun wheel of the stator could be disconnect from the stator and could be fixed to the rim for ratio **1:1**

If the sun wheel of the stator is disconnected from the stator and from the rim all parts can rotate freely

Verification Tests

Motor test bench

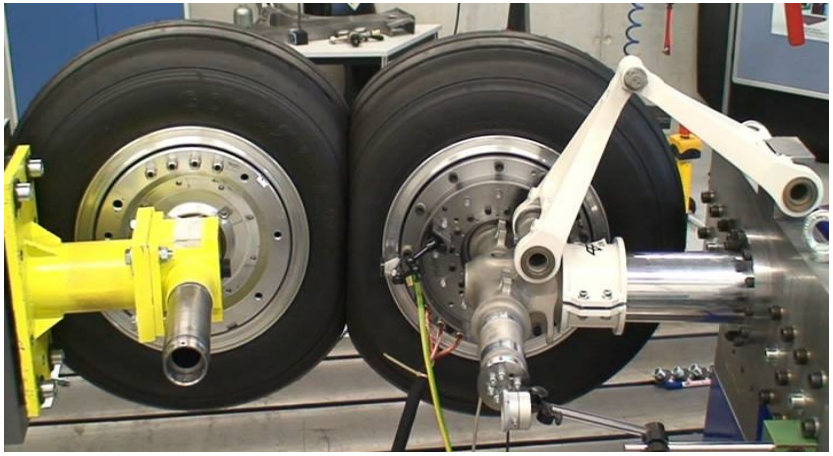




EMC test

Complete drive on roller test bench

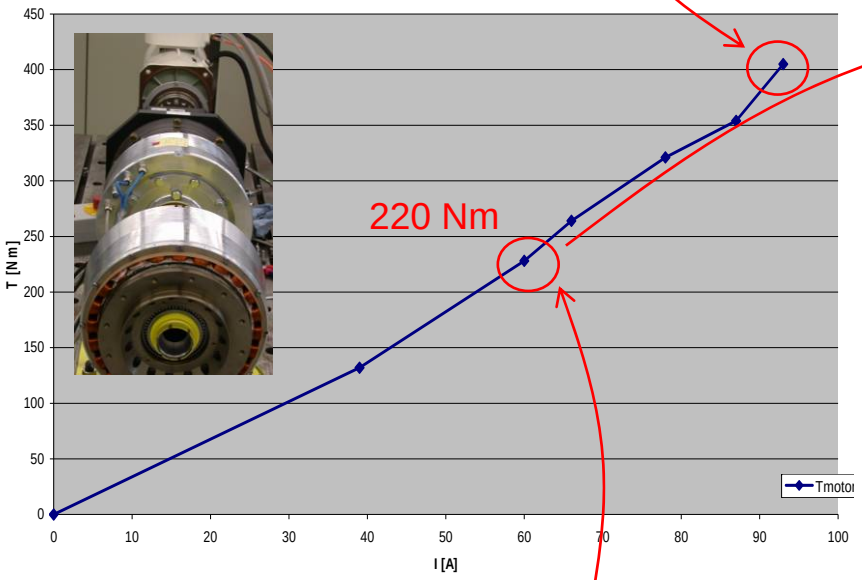
Static load test



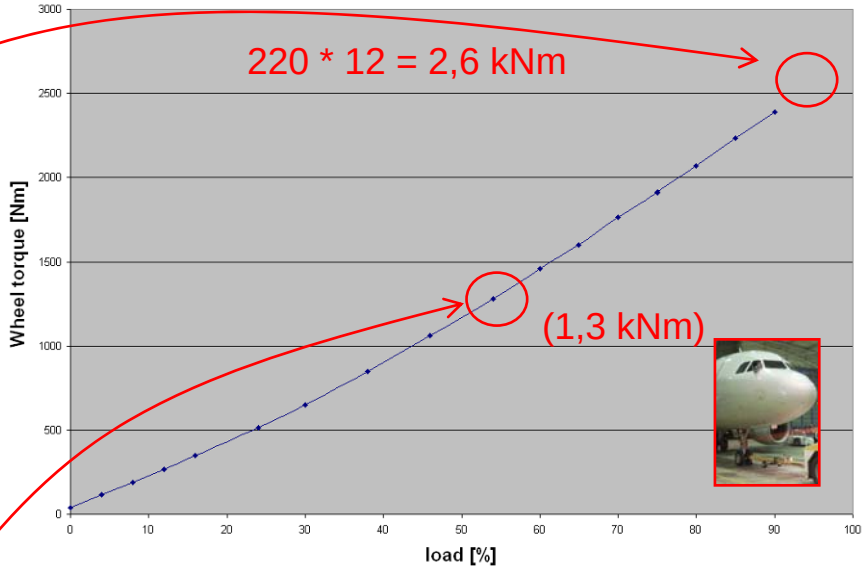
EMC: Electromagnetic Compatibility

Torque Measurements

Motor overloaded for break away operation



Torque of one motor (at gear ratio 1:1)

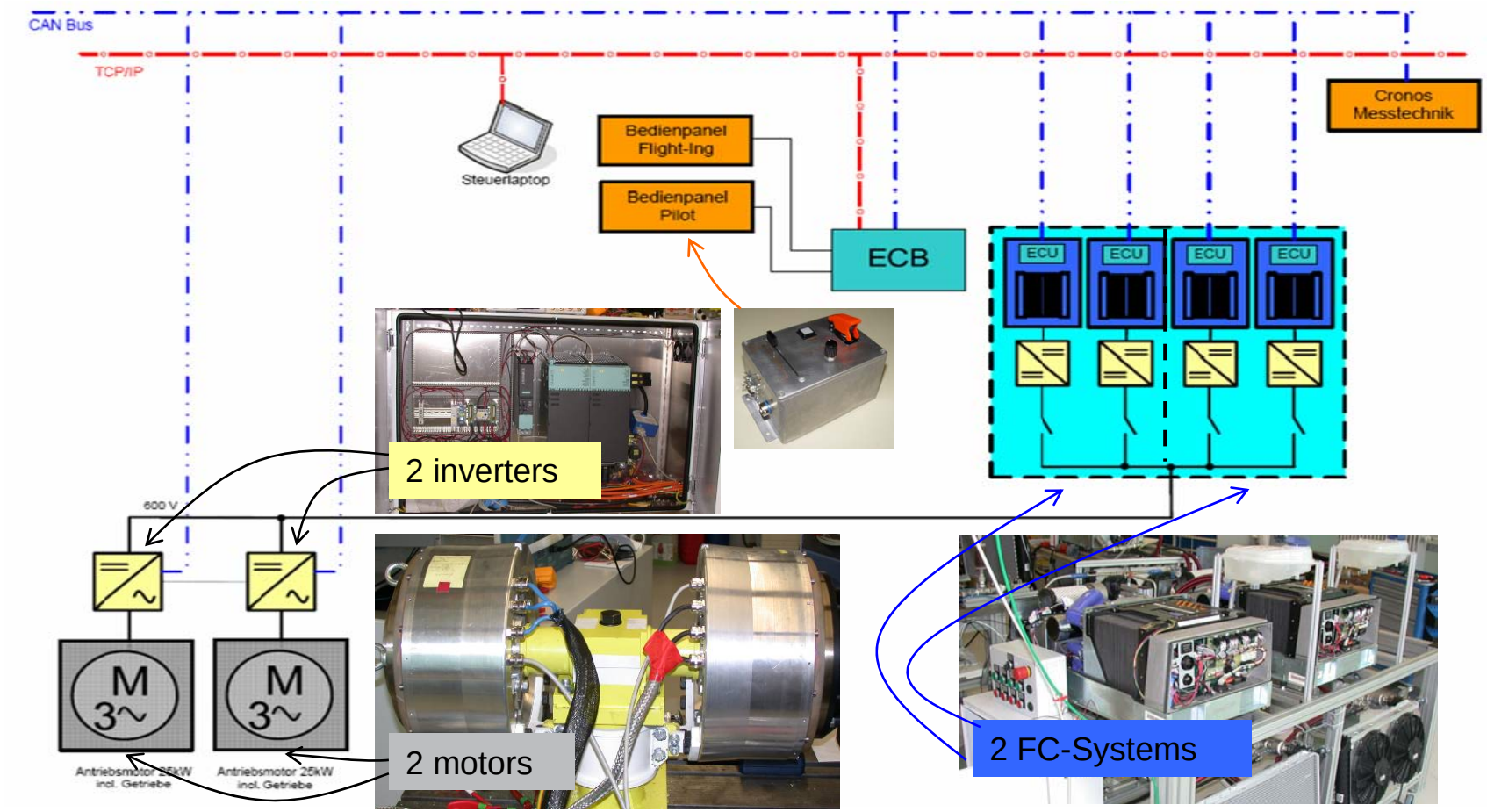


Torque of one wheel (at gear ratio 1:12)

Taxiing on plane surface

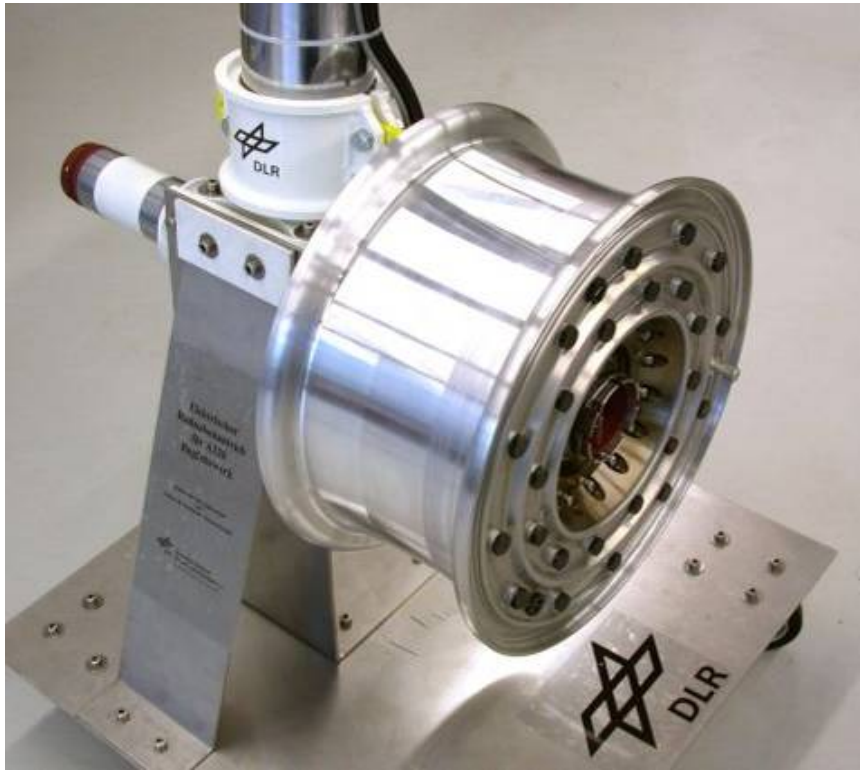
Taxiing with slope 1,5 %

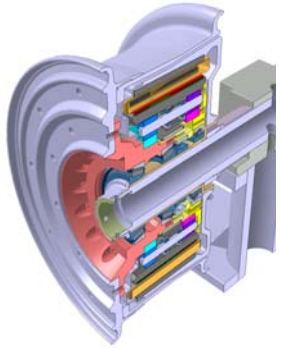
Architecture of the Drive System



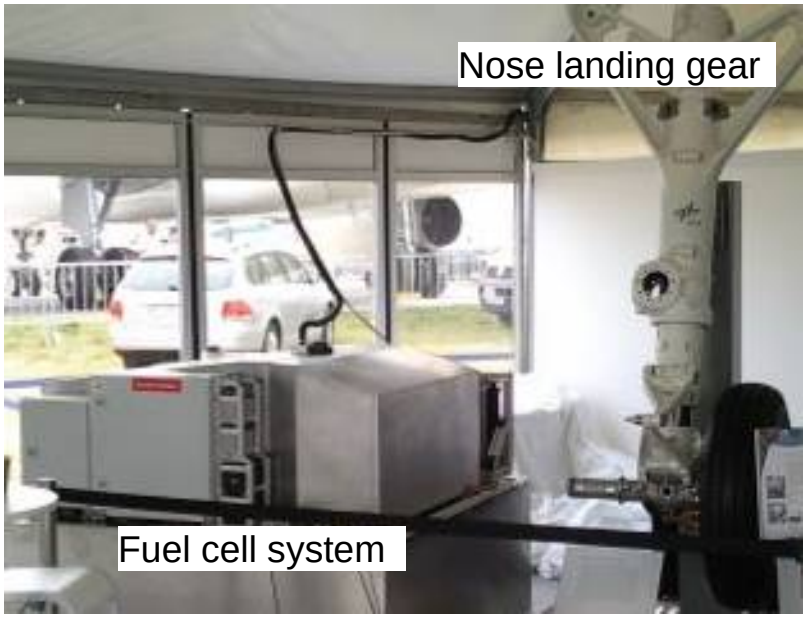
2 motors are fed by 2 fuel cell systems with 2 x 25 kW each

Electric Wheel-Hub-Drive for Aircraft Application





Taxiing system shown on ILA 2010



ILA: International aerospace exhibition, Berlin, Mai 2010

Thank you for your attention