Why extended temperature range?

- stack for **automotive applications**:

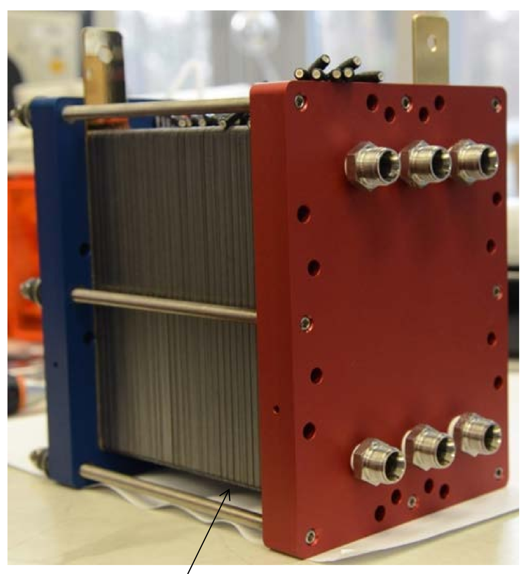
able to perform **transient operation** at high load even with critical cooling conditions (higher power required → higher heat production):

- long uphill drive
- driving in hot areas, e.g. deserts (reduced cooling)

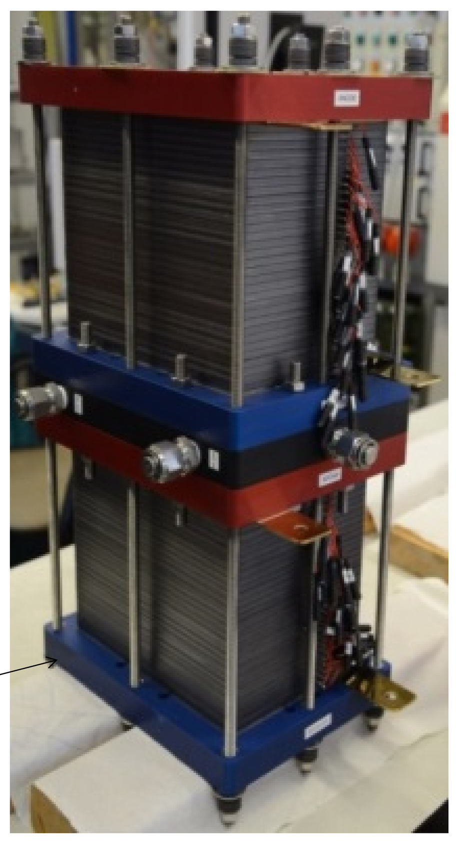
- **downsizing of cooling system**:

lower cooling power is necessary (increased heat dissipation) if higher stack temperature is allowed:

- shorter cooler operating time (energy/fuel saving)
- smaller cooler size (space/weight saving in vehicles)



stack module with 30 cells



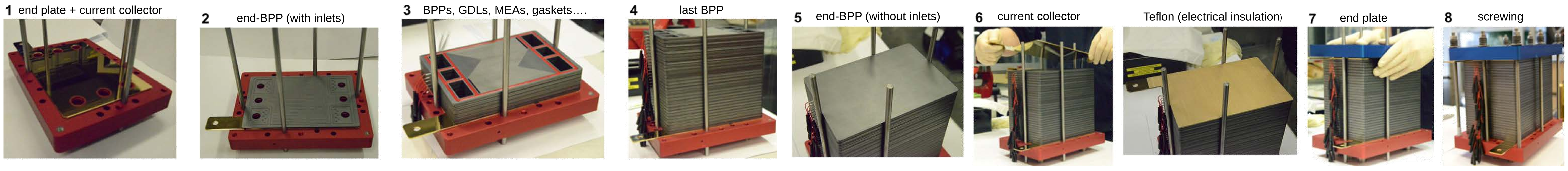
full stack with 60 cells

Wide-temperature-range (WTR) stack goals

- development of a PEMFC stack:
  - 2.5 – 5 kW_{el}
  - 30 – 60 cells
- feasibility of WTR-conditions:
  - extended temp. range **up to 120 °C**
  - **20 temperature cycles** feasible
    - duration of each cycle: 65 min
    - aim: reversible maximum power loss at 120°C with unmodified humidification: 30 %
- durability test:
  - long-term test over **1000 h**

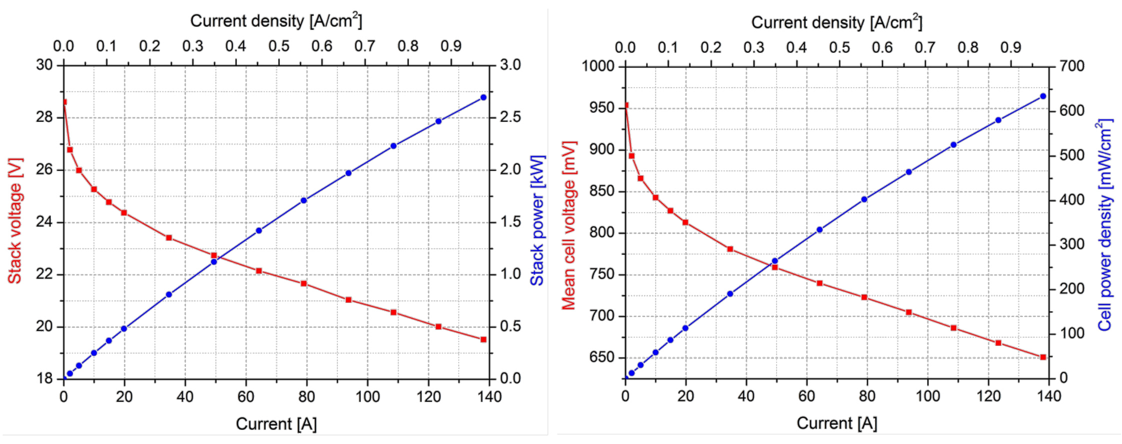
Assembling of 30-cell stack module

1 end plate + current collector; 2 end-BPP (with inlets); 3 BPPs, GDLs, MEAs, gaskets….; 4 last BPP; 5 end-BPP (without inlets); 6 current collector; Teflon (electrical insulation); 7 end plate; 8 screwing



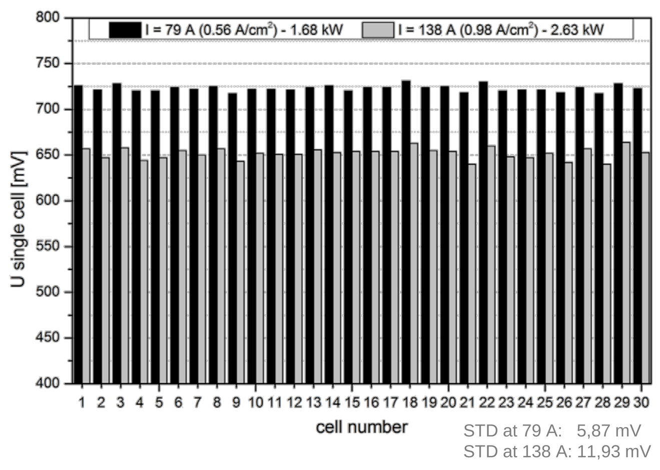
Experimental results

Polarization curve (BoL)



ca. 2.7 kW_{el} at 19.5 V (ca. 650 mV/cell) and 140 A (ca. 1 A/cm²)

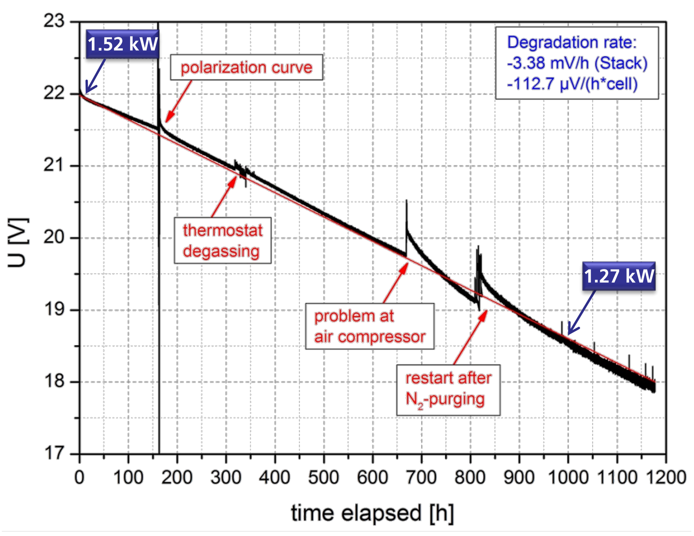
Parameter	Set-up value
T_{stack}	80 °C
$p_{anode} = p_{cathode}$	1.5 bar_{abs}
RH_{anode}	15 %
$RH_{cathode}$	60 %
λ_{anode}	1.5
$\lambda_{cathode}$	2.5
t_{dwell}	5 min



- high homogeneity of 30 single cell voltages
- all 30 cells are fed homogeneously with reactants

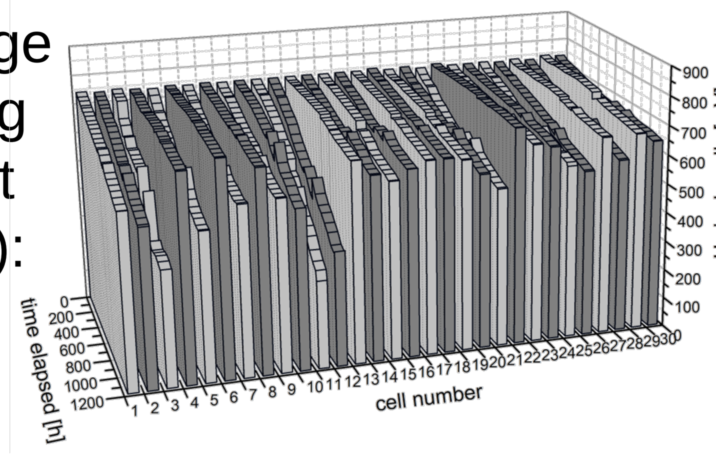
Long-term test

- 1200 h at 70 A: output power 1.5 kW_{el}
- degradation rate nearly constant: linear voltage drop
- 16 % power loss in 1000 h (ca. 250 W, 3.5 V) → 0.016 %/h (250 mW/h or 8.3 mW/(h·cell))

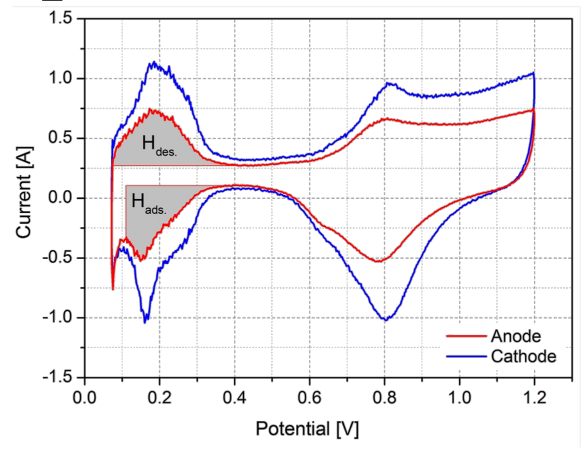


Parameter	Set-up value
T_{stack}	80 °C
I_{stack}	70 A (0.5 A/cm²)
$p_{anode} = p_{cathode}$	1.5 bar_{abs}
RH_{anode}	15 %
$RH_{cathode}$	60 %
Q_{anode}	22 l/min
$Q_{water, anode}$	52 g/h
$Q_{cathode}$	87.3 l/min
$Q_{water, cahode}$	969 g/h
λ_{anode}	1.5
$\lambda_{cathode}$	2.5

single cell voltage behaviour during long-term test at 70 A (0.5 A/cm²):



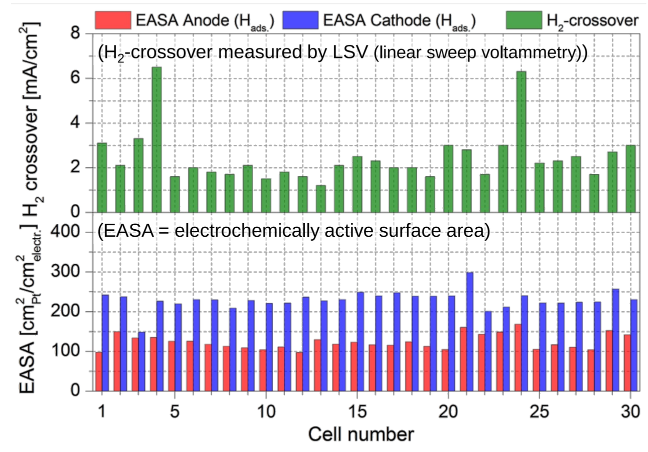
Cyclic voltammetry and H_2-crossover



Parameter CV	Set-up value
T_{stack}	80 °C
p	1 bar_{abs}
Q (H_2)	4.25 l/min
Q (N_2)	8.50 l/min
RH (H_2/N_2)	100 %
Voltage range	0.07 – 1.2 V
Sweep rate	20 mV/s
N. cycles	5

Aim: identify possible stressors responsible for performance loss:

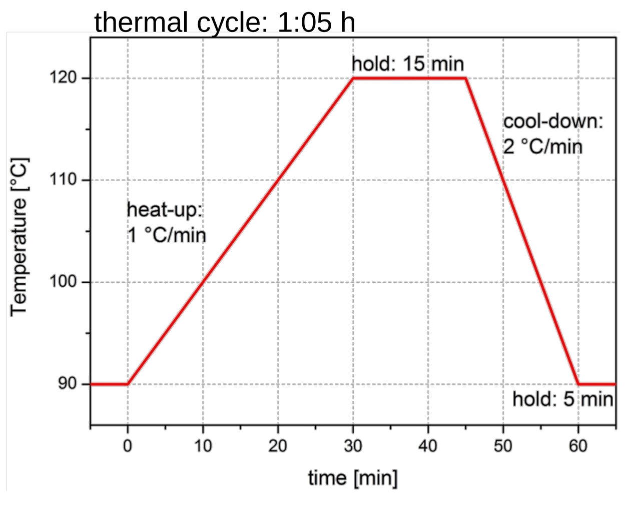
- catalyst degradation → decrease of EASA by catalyst growth/washout
- carbon corrosion
- membrane degradation
- chemical/mechanical degradation



Parameter H_2-crossover	Set-up value
T_{stack}, p, Q (H_2/N_2), RH (H_2/N_2)	same as for CV measurements
Voltage range	0.07 – 0.80 V
Analysed range	0.35 – 0.60 V
Sweep rate	2 mV/s

$$EASA\ [cm^2_{Pt}/cm^2_{el}] = \frac{q_{Pt}[C/cm^2]}{\Gamma[\mu C/cm^2_{Pt}]}$$

Thermal cycles 90–120 °C

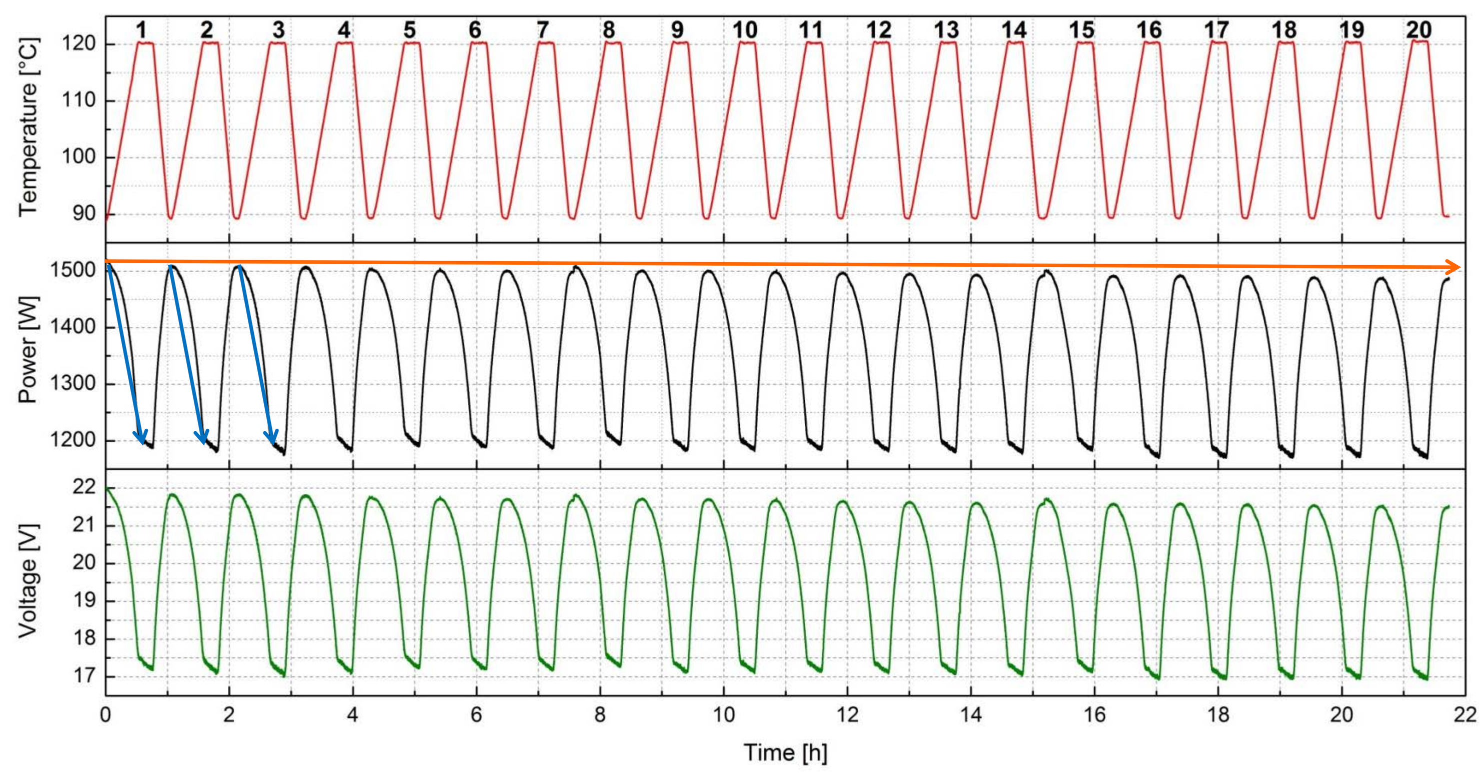


Parameter	lower limit	upper limit
T_{stack}	90 °C	120 °C
$p_{anode} = p_{cathode}$	1.5 bar_{abs}	
I_{stack}	70 A (0.5 A/cm²)	
Q_{anode}	22 l/min	
$Q_{water, anode}$	907 g/h	
$Q_{cathode}$	87.3 l/min	
$Q_{water, cathode}$	2464 g/h	
RH_{anode}	100 %	35 %
$RH_{cathode}$	80 %	28 %
λ_{anode}	1.5	
$\lambda_{cathode}$	2.5	

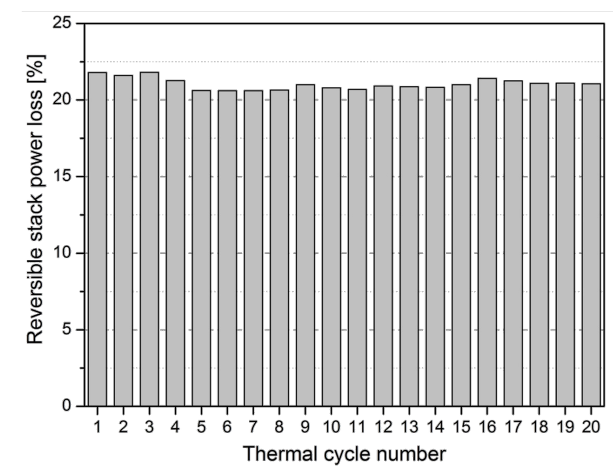
- 20 thermal cycles at 70 A (0.5 A/cm², 1.5 kW)
- cycle duration: 1:05 h →
  45 min transient operation (90 → 120 °C) +
  15 min cool-down (120 → 90 °C) +
  5 min recovery (90 °C)
- gas humidification: on both sides 100 % at 90 °C (cycle start), then no variation
- goal: max. 30 % power loss within a cycle

Information obtained on:

- reversible power loss within a cycle → membrane drying
- irreversible degradation → stack stability over all cycles



Irreversible stack performance drop is small enough for automotive applications



Results:

- stable reversible power loss within a cycle: 21 ± 1 %
- irreversible stack power loss at 90 °C: 33 W in 22 h → < 0.1 %/h (1.5 W/h or 50 mW/(h·cell))
- good stack stability over all cycles

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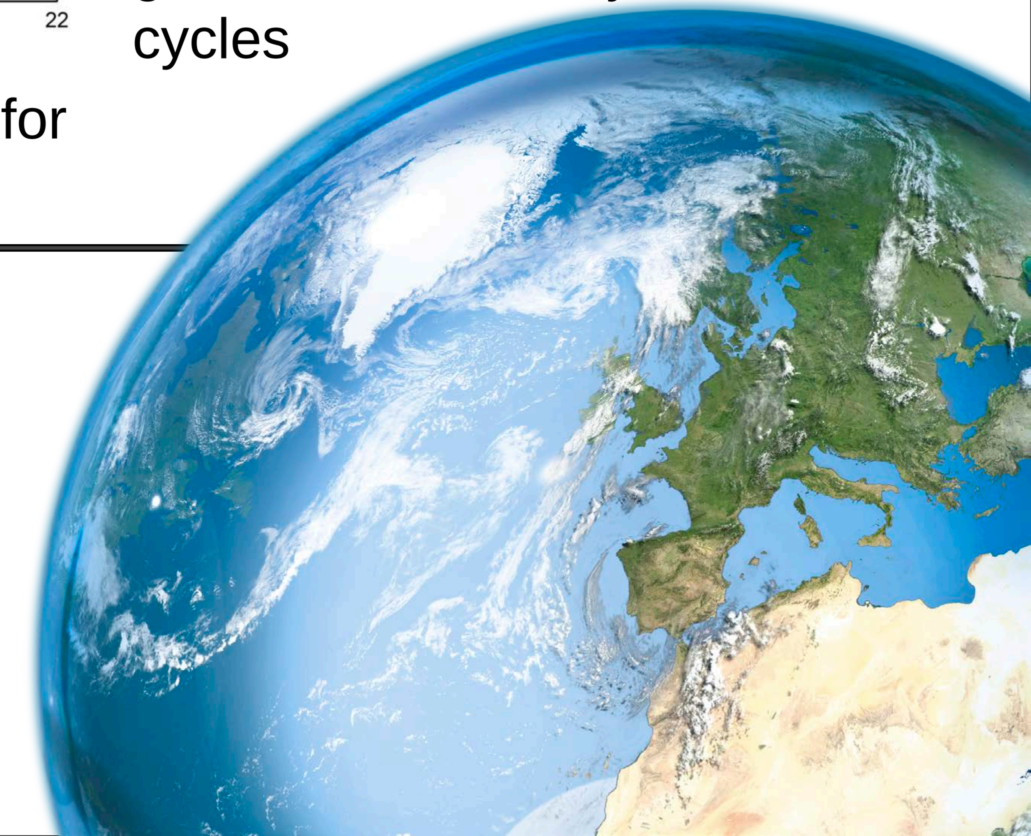
Knowledge for Tomorrow

Wissen für Morgen



DLR Deutsches Zentrum für Luft- und Raumfahrt
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