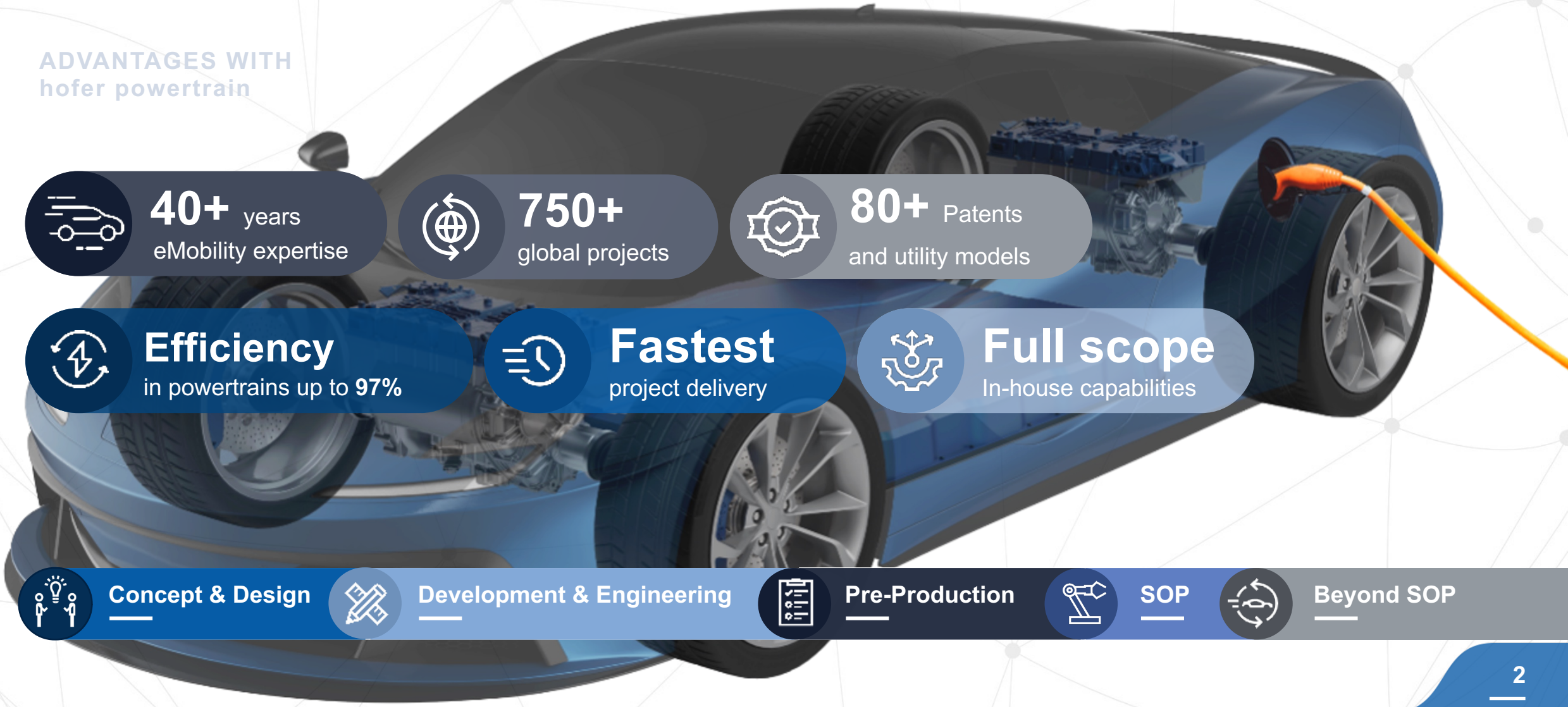
Cost-effective approach to design optimisation for battery performance and lifespan

Unique early fault detection & swelling analysis tool

hofer powertrain

ADVANTAGES WITH
hofer powertrain



40+ years
eMobility expertise

750+
global projects

80+ Patents
and utility models

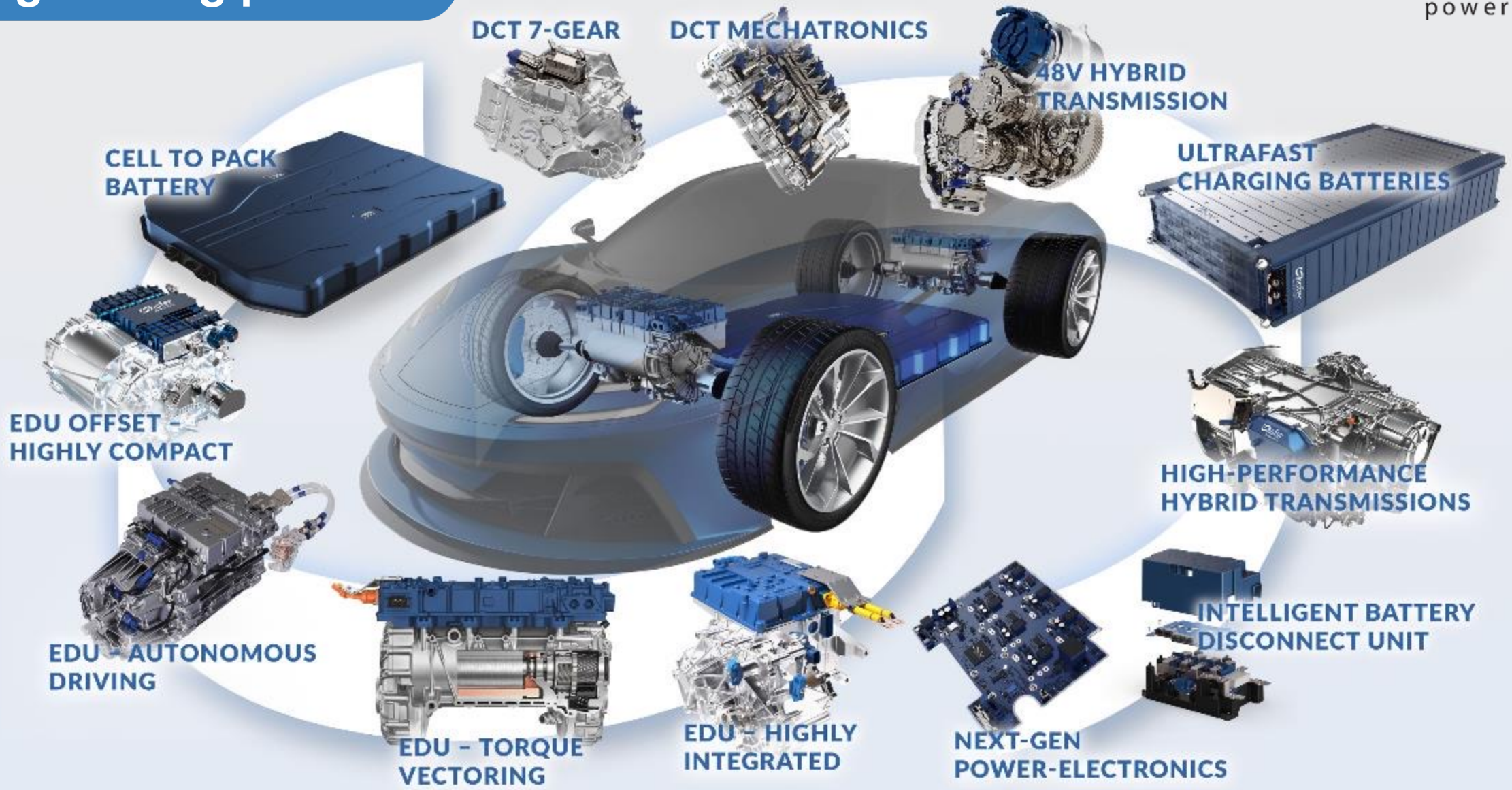
Efficiency
in powertrains up to **97%**

Fastest
project delivery

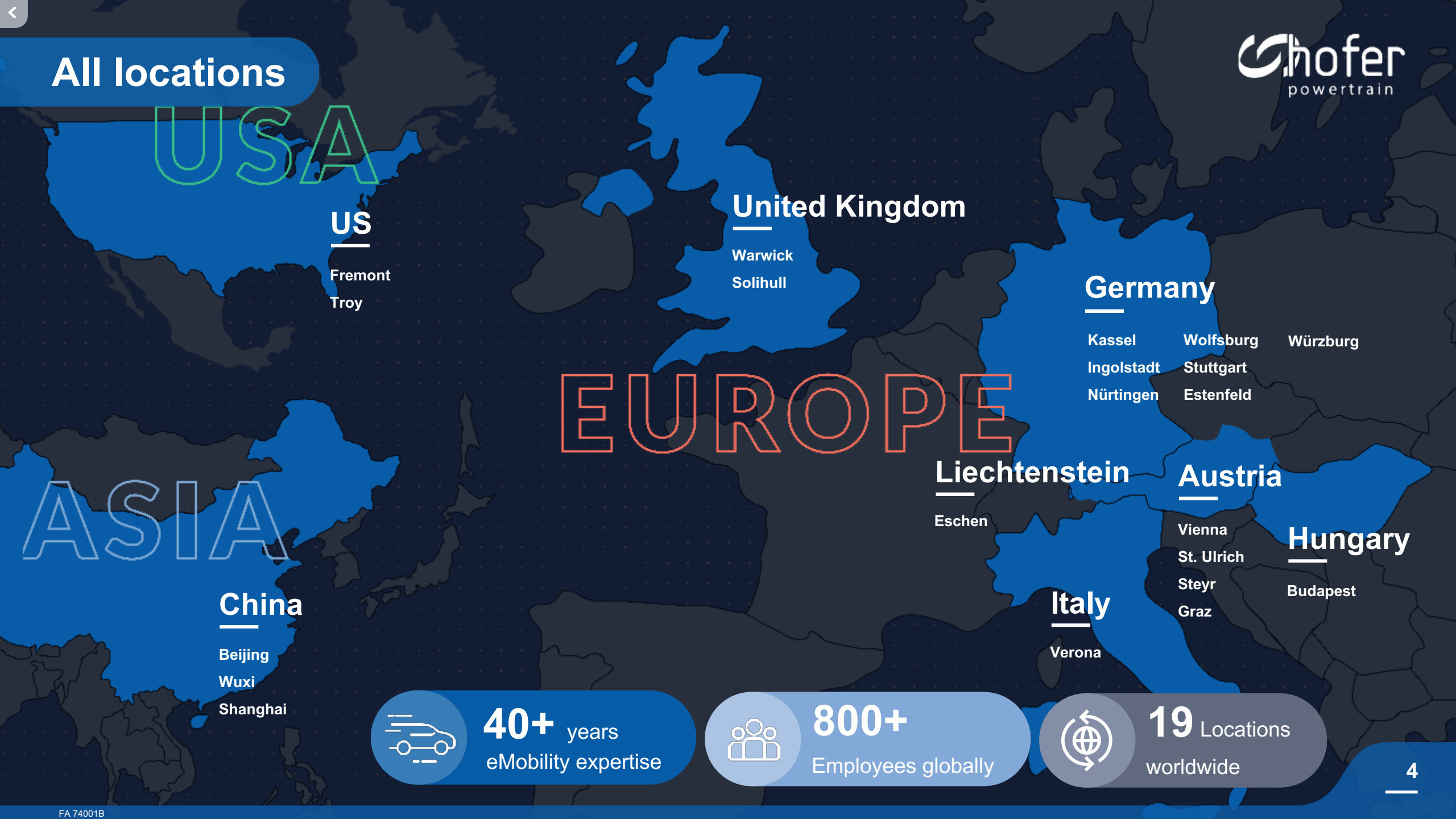
Full scope
In-house capabilities

Concept & Design — **Development & Engineering** — **Pre-Production** — **SOP** — **Beyond SOP**

Engineering portfolio



All locations



US

Fremont

Troy

United Kingdom

Warwick

Solihull

Germany

Kassel

Ingolstadt

Nürtingen

Wolfsburg

Stuttgart

Estenfeld

Würzburg

Liechtenstein

Eschen

Austria

Vienna

St. Ulrich

Steyr

Graz

Hungary

Budapest

Italy

Verona

China

Beijing

Wuxi

Shanghai

40+ years eMobility expertise

800+ Employees globally

19 Locations worldwide

Key characteristics EV batteries

High Energy density is crucial for extending the **range** of EVs

Exceptional thermal management

Maximum safety & no battery **malfunctions**

Highest battery longevity / min. degradation

Radical cost reduction

Faster times to market through higher maturity of solutions

Main challenges for EV battery development

Challenges within the mechanical structure:

Structural deformation of battery cells effecting overall structure

potentially causing internal short circuits, high heat and gas

Electrode material degradation (aging)

preventing reduction of the effective surface area for charge and discharge

Mechanical fatigue in the battery cell

Increases the electrical resistance within the battery cell

Thermal runaway

High insulating heat shields with a low heat conductivity

We develop solutions to:

Maintain the integrity

Robust mechanical structure within the battery module

Keep performance at a maximum

Low Internal resistance, minimum weight, optimal SoH, reduction of active material

Realize robust, safe battery systems

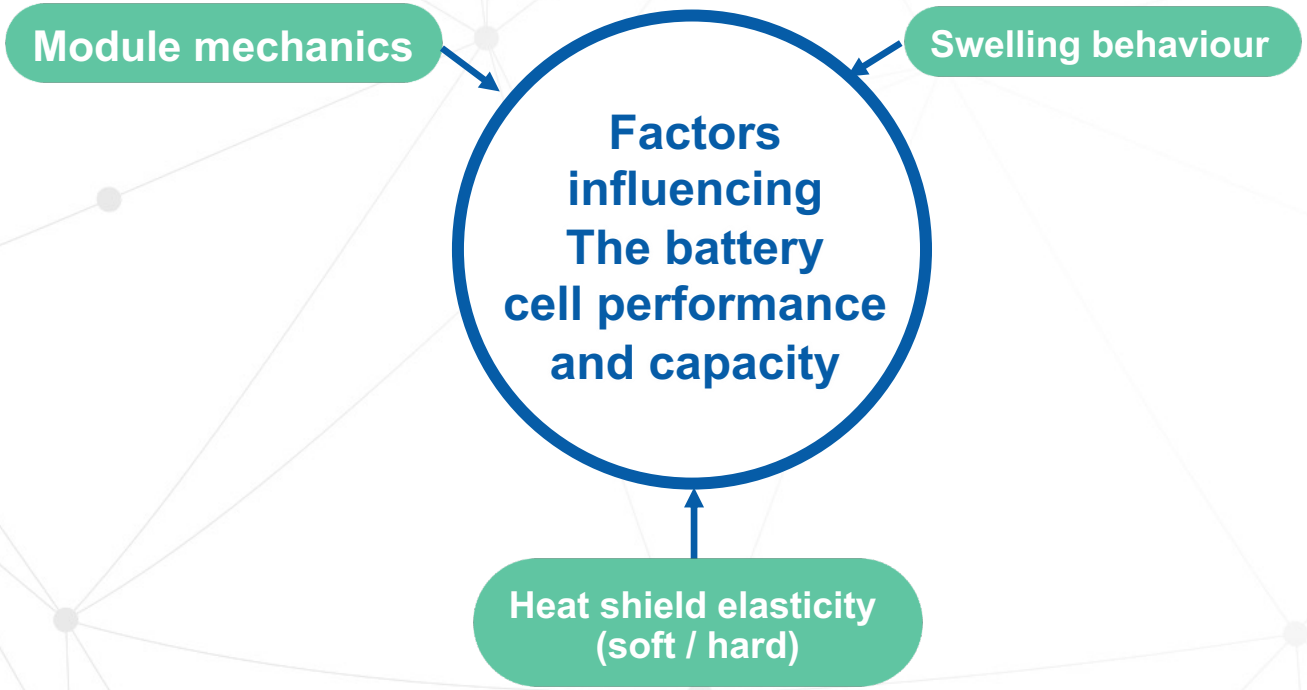
Prevent or contain thermal runaway

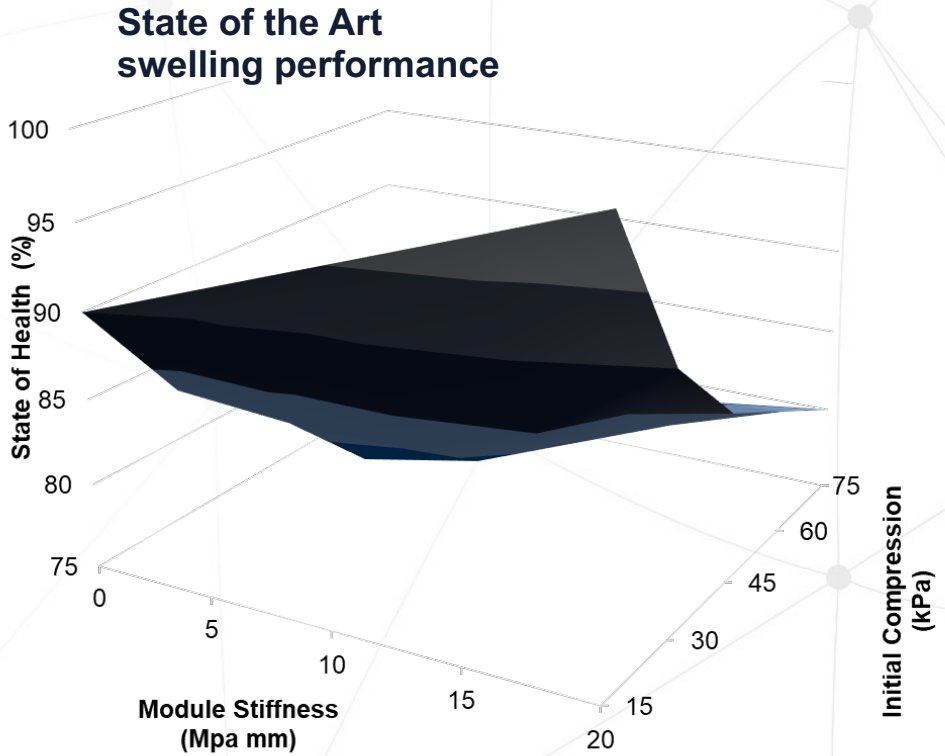
Increase energy density

Best combination of mechanical parts, lowest swelling, thinnest heat shields

Factors of influence on battery cell performance and capacity

It is essential to understand the relationship between the module mechanics and the effect on the cell performance





Cells with a high energy content prone to swell even more.

Cell focus battery development approach

Traditional approach: Trial & Error

Time and cost consuming

Testing mostly focused on module level

Mechanical load on cells unknown

Less control over the key characteristics

Early SoH assessment not possible

No feedback if the mechanical design is right

Determination of the SoH only under fixed conditions possible

Only one clamp force and one module stiffness

Our approach: Highly structured

Precise analysis of each cell / cyclisation before module testing

Charge cycling under various load conditions

Optimal operating condition of the cell are explored

Determination of the minimal swelling behavior of each cell

Factors of influence are fully characterized to ensure a robust mechanical module design

Early mature design approach

1-2 weeks first results

A sample development

- **Design acceleration**
- Determine optimal **cell requirements** to **inform module design**

- **Significant additional information and validated data** for adjusting and comparisons with real designs
- **No design freeze**

Every 2 weeks

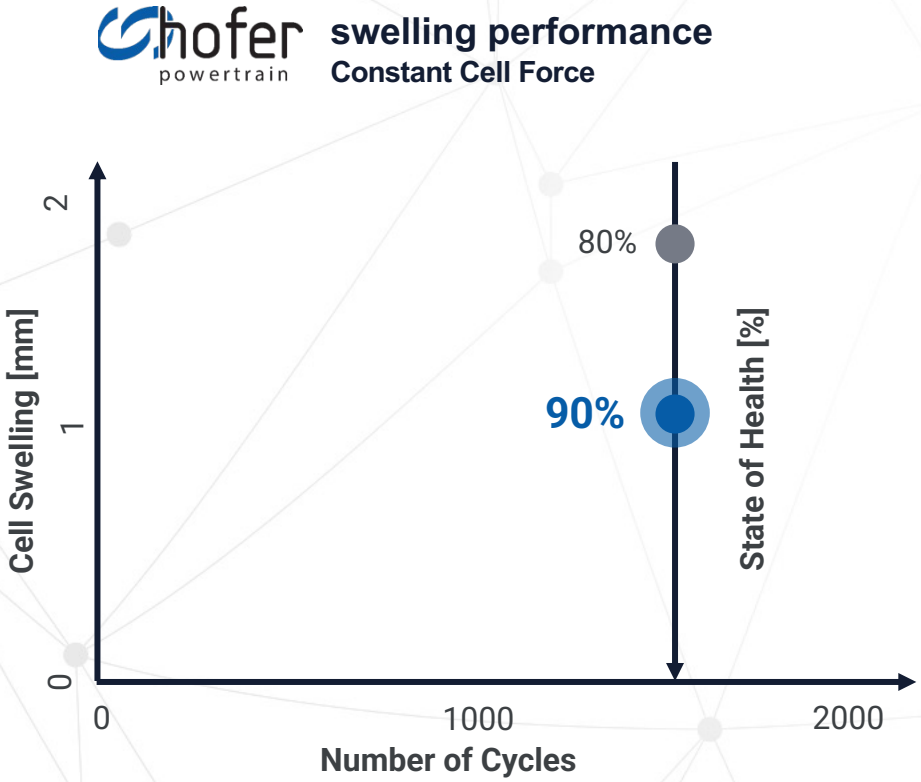
B sample development

- Highly mature systems
- Acceleration of all design phases

Extremely fast times to market

In some cases, C sample maturity can be reached in functionality during A sample design

Improvement of key battery cell parameters



- Our approach **reduces swelling behaviour from 2mm to 1mm after 1500 cycles**
- The state **SoH is higher by 10% after 1500 cycles**

- Reduced aging
- Better SoE
- Up to 10% more SoH

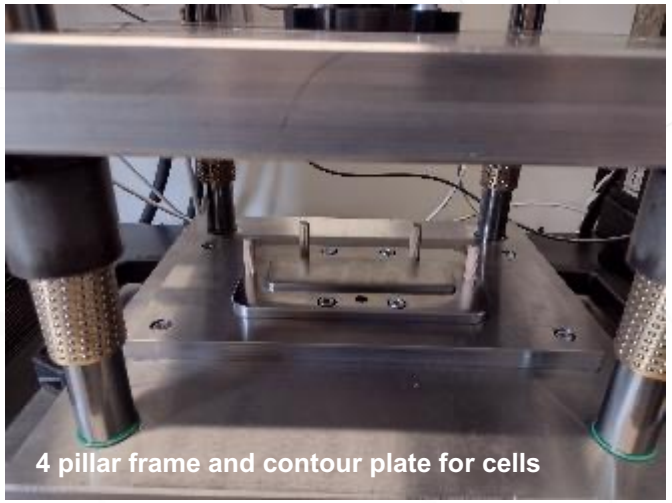
Elasticity measurements

Purpose of the test:

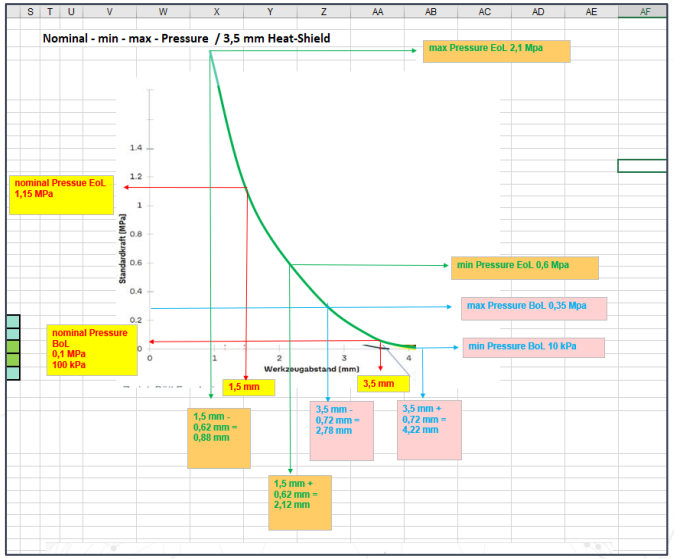
Determination of the heat shield/swell pad elasticity with a travel force measurement machine

Results:

- Precise elasticity curve of the heat shield
- Selection of the optimal heat shield / swell pad elasticity to compensate swelling behaviour of the cell



4 pillar frame and contour plate for cells



Test Machine

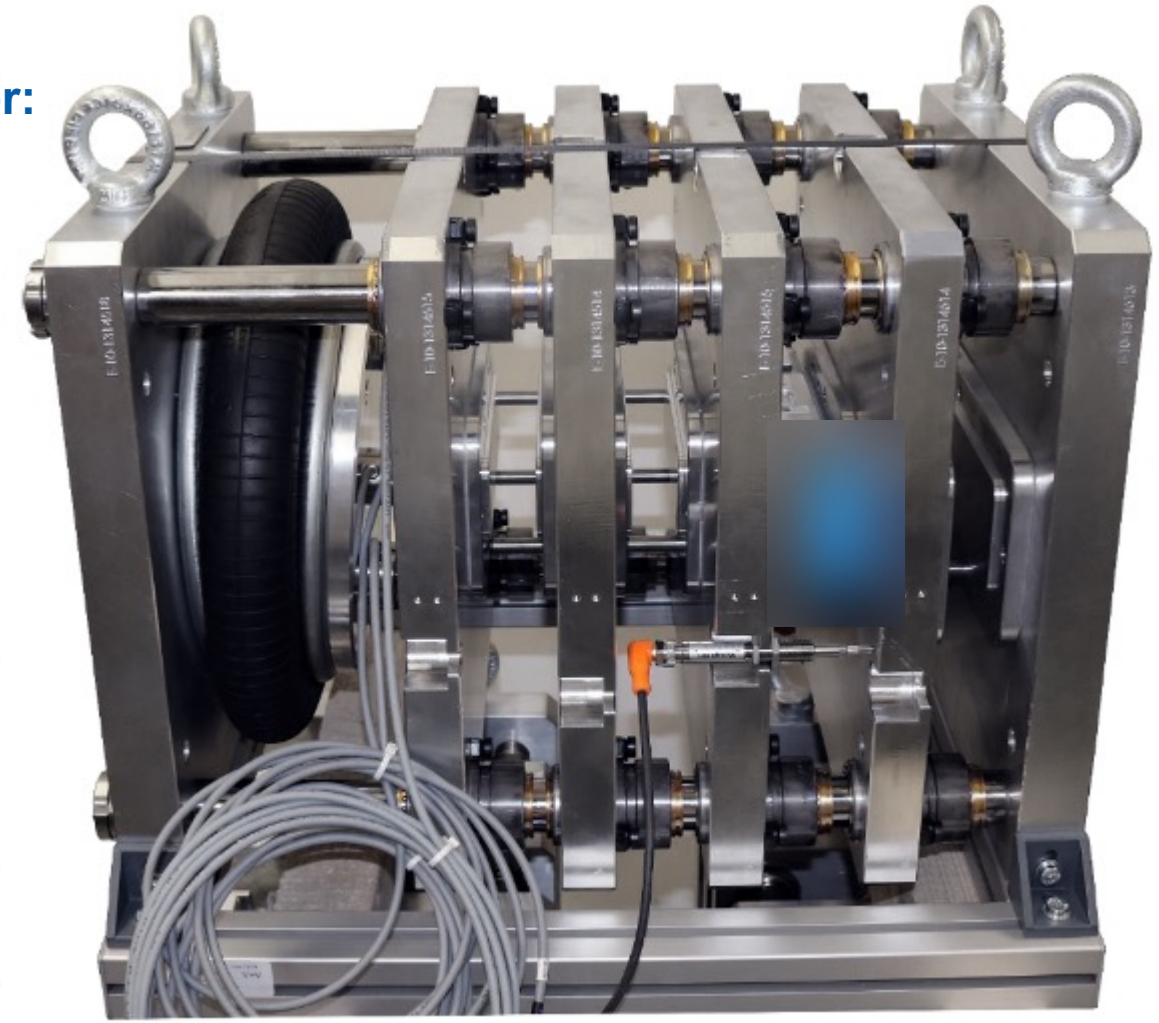
Dilatometer test

Steps for early determination of cell aging behavior:

- **Cells** are aligned and **connected** within the jig **to the cell tester**
- **Constant force applied** via a pneumatic cylinder & **regulated** accurately by a PID controller
- Travel **sensor monitors swelling**; capacity and internal resistance checked **every 50 cycles**, **OCV every 200 cycles**

Results:

We identify optimal clamp force to ensure safe and efficient operation of the battery module.



Jig for dilatometer test

Testing Outcomes and Impact on Battery Performance

Quantified swelling per cycle and overall lifetime under a constant clamp force

optimizing cell longevity and performance

Evaluate the impact of preload force on SoH

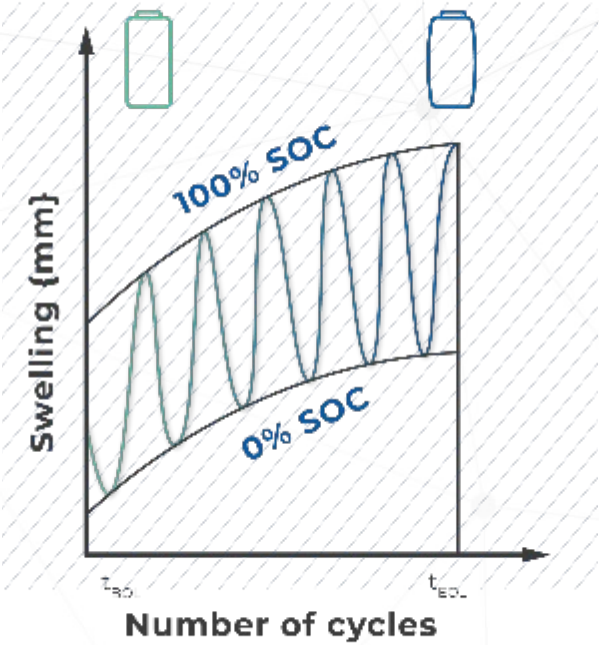
enabling targeted improvements to maintain cell integrity over its lifespan

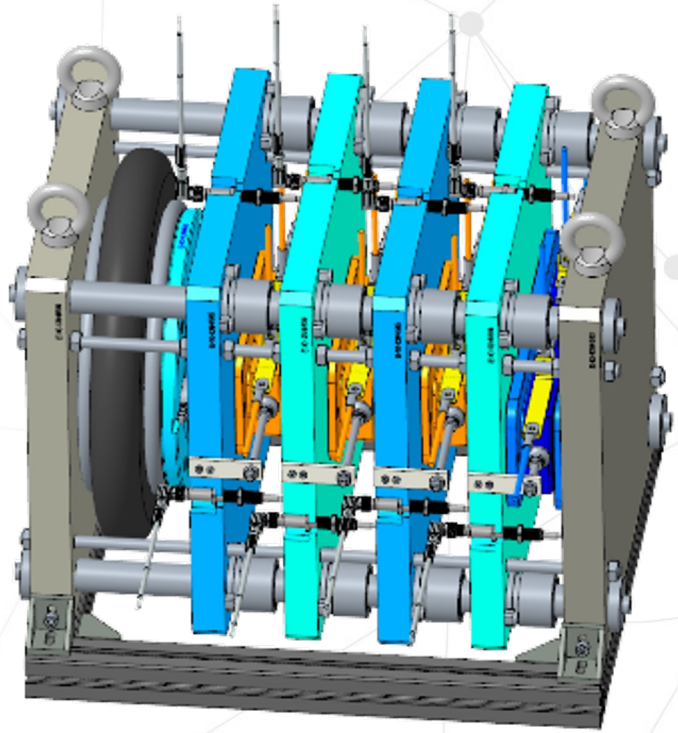
Continuous monitoring of Open Circuit Voltage (OCV), SoH, and internal resistance

assessment and predictability of battery lifespan

Design of optimal heat shields and swell pads

ensuring functional efficiency and safety of battery cells under operational stresses





Fast-track battery design – summary

Up to **10%** less degradation (fewer capacity losses)

Increased overall range by **10%**

Up to **10%** less active material at a constant capacity (expected lifetime)

Rapid, goal-orientated development, less effort (C-phase functionality in A-phase)

Let us implement the future today

Visit us at www.**hofer.de**

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