How to solve the ten most significant Fuel Cell and Electrolyzer Testing Challenges

AVL Webinar

Today’s Presenters

Christoph Supper

Skill Team Leader Unit Under Test Preparation

Joined AVL in 2003

Since 2021 Test Factory Responsible for Product Team Fuel Cell

Horst Kiegerl

Specialist Fuel Cell Testing

Joined AVL and Fuel Cell Industry in 2002

Stefan Scheidel

Senior Development Engineer Methodology

Joined AVL in 2013

Methodology engineer ever since

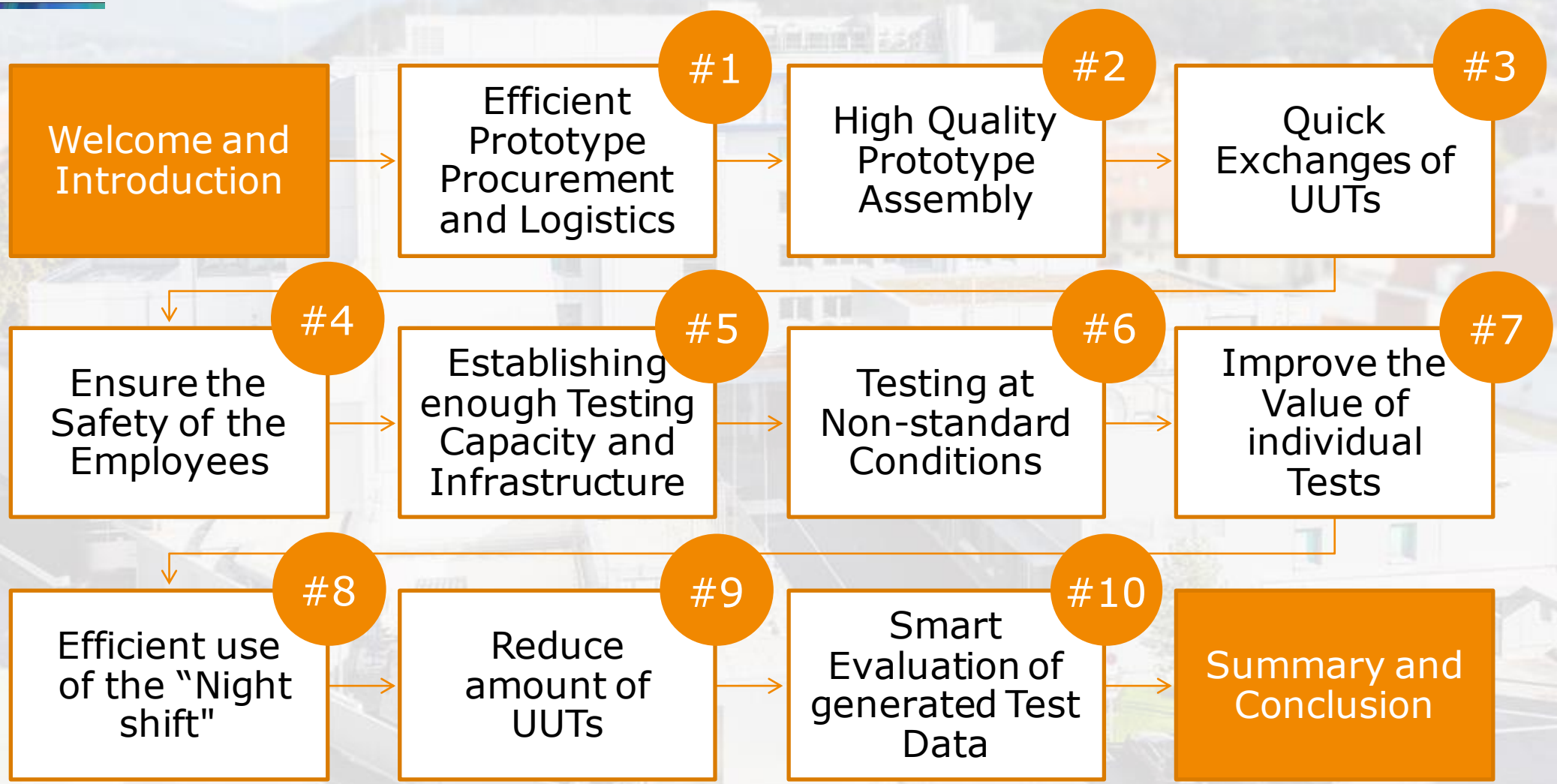
Markus Kammerhofer

Business Analyst Big Data Intelligence

Joined AVL in 2019

Helping engineers to get more out of measurement data

Content


Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

We Owe It to the Planet

It is our duty as an organization to contribute to the resolution of social, cultural and global issues – especially with regards to environmental protection, sustainability and global emission reduction.

AVL Fuel Cell Global Footprint

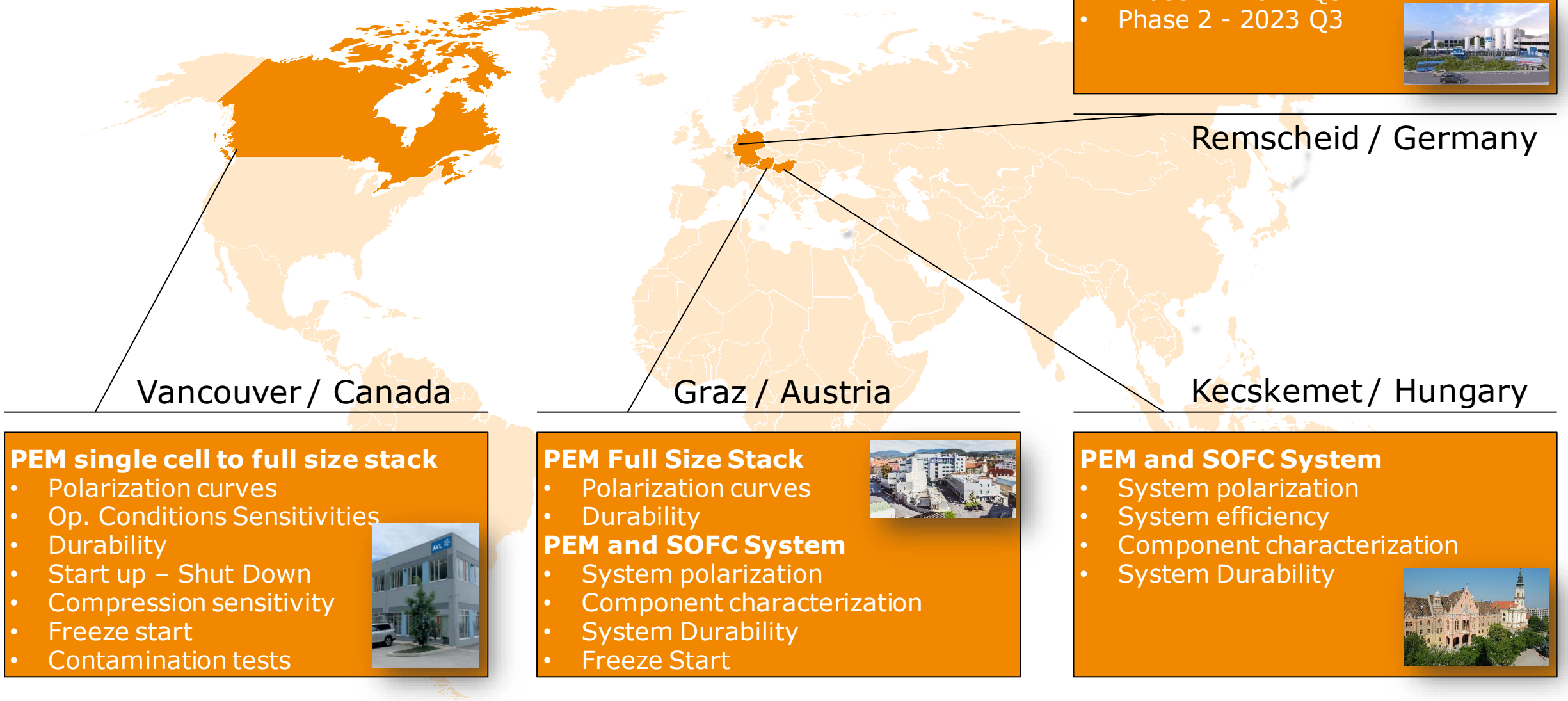
- H_2 & fuel cell development since 2002
- H_2 & Fuel Cell Tech-Centers
  - Graz, AT
  - Vancouver, CA
  - Kecskemet, HU
  - Warsaw, POL - new
  - Remscheid, GER – new
- About 500 engineers in engineering, testing & simulation
- More than 170 granted or applied patent families

Hydrogen & Fuel Cell Test & Development Center – Graz / Austria

AVL Fuel Cell Canada – Vancouver / Canada

Stack Test and Prototype Lab - Vancouver / Canada

AVL Fuel Cell and Electrolyser Testing Infrastructure



PEM and SOC High Power System
(2022 Q1)
- >2MW Fuel cell, electrolysis and power systems testing
- Phase 1 - 2022 Q3
- Phase 2 - 2023 Q3

Remscheid / Germany

Vancouver / Canada

PEM single cell to full size stack
- Polarization curves
- Op. Conditions Sensitivities
- Durability
- Start up – Shut Down
- Compression sensitivity
- Freeze start
- Contamination tests

Graz / Austria

PEM Full Size Stack
- Polarization curves
- Durability

PEM and SOFC System
- System polarization
- Component characterization
- System Durability
- Freeze Start

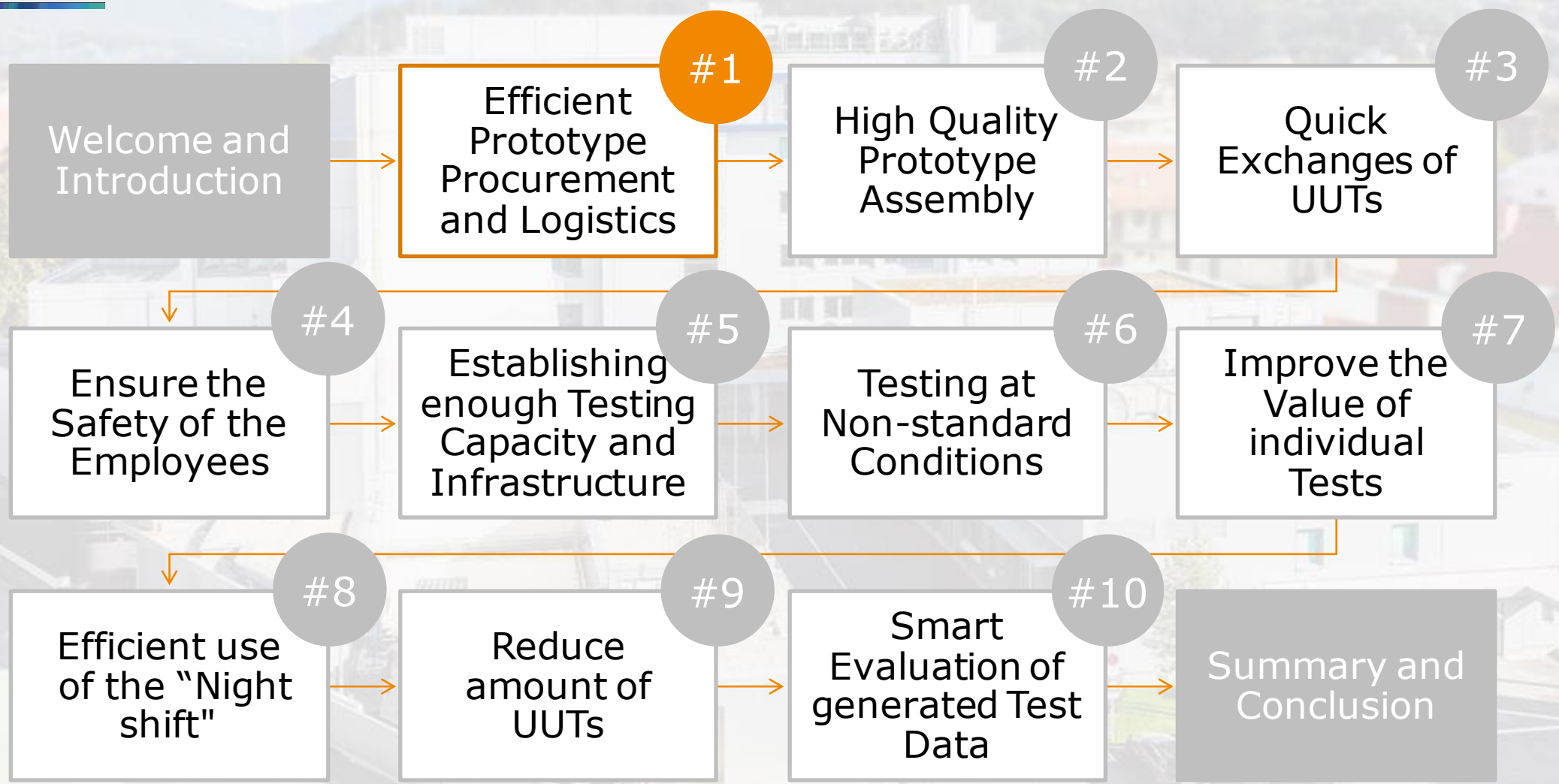
Kecskemet / Hungary

PEM and SOFC System
- System polarization
- System efficiency
- Component characterization
- System Durability

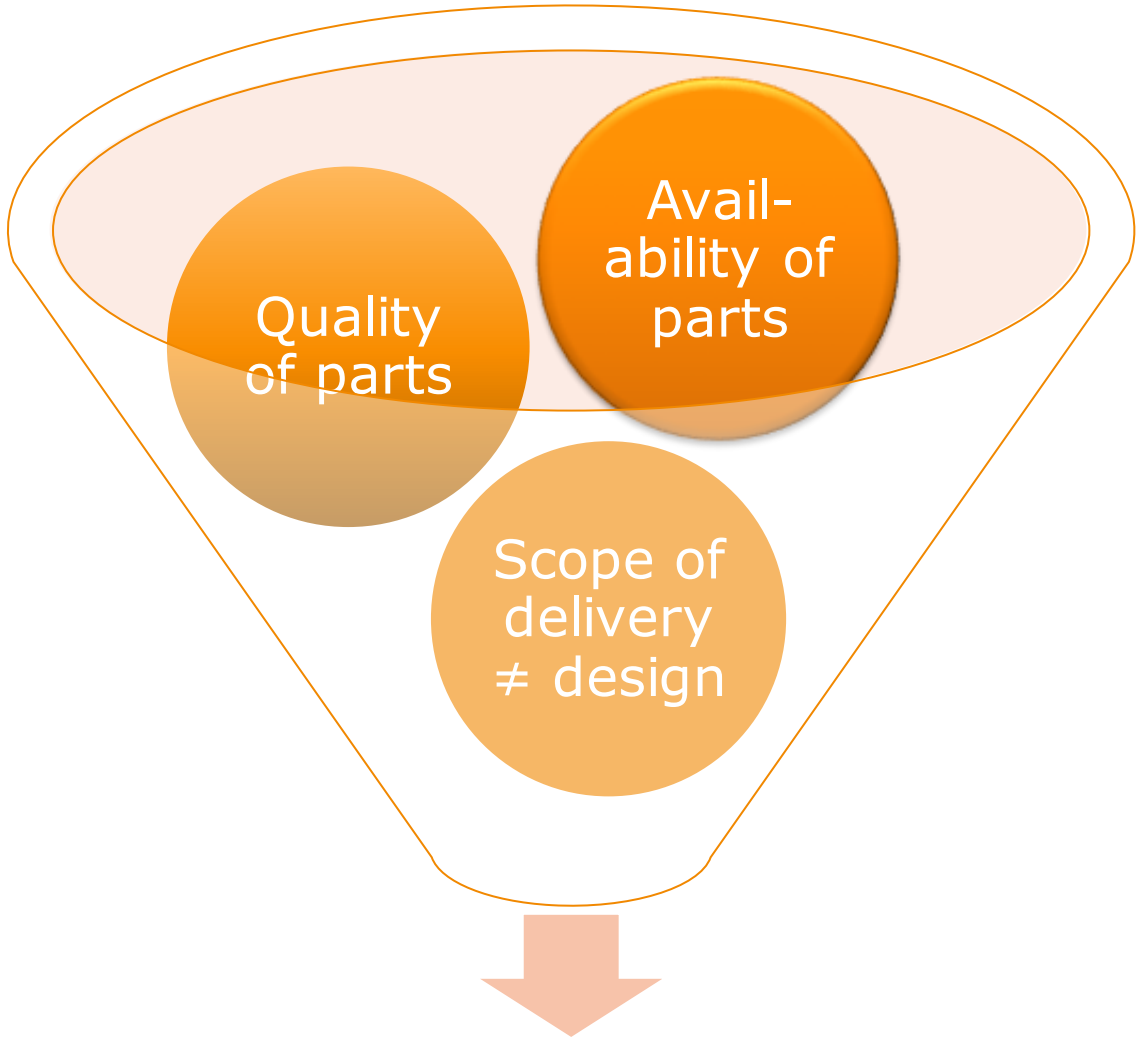
AVL Test Factory - a ONE-STOP-SHOP

- >70 years experience in Automotive Testing
- >1.250 experienced & skilled Team
- >300 Testbeds of different types
- Cutting-edge measurement technologies
- Best in class test management & execution systems

Content


Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

Efficient Prototype Procurement and Logistics Challenges



Start Unit Under Test (UUT) Build

Efficient Prototype Procurement and Logistics

- Procurement milestones
- Scope of delivery
- Potential suppliers
- Final release dates

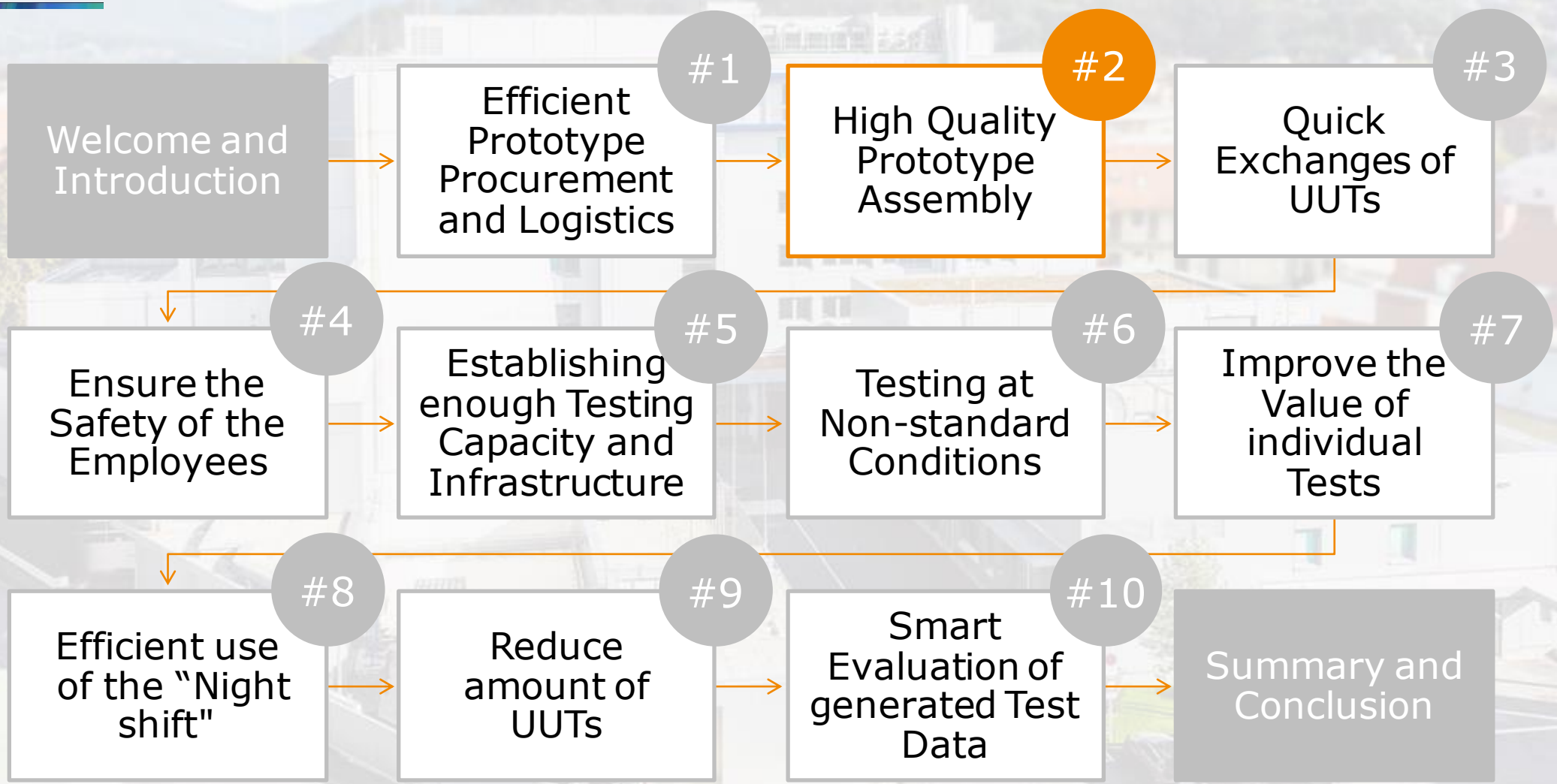
- Finalizing needed parts
- Purchasing

- Activities at suppliers
- Parts income
- Recording for further use

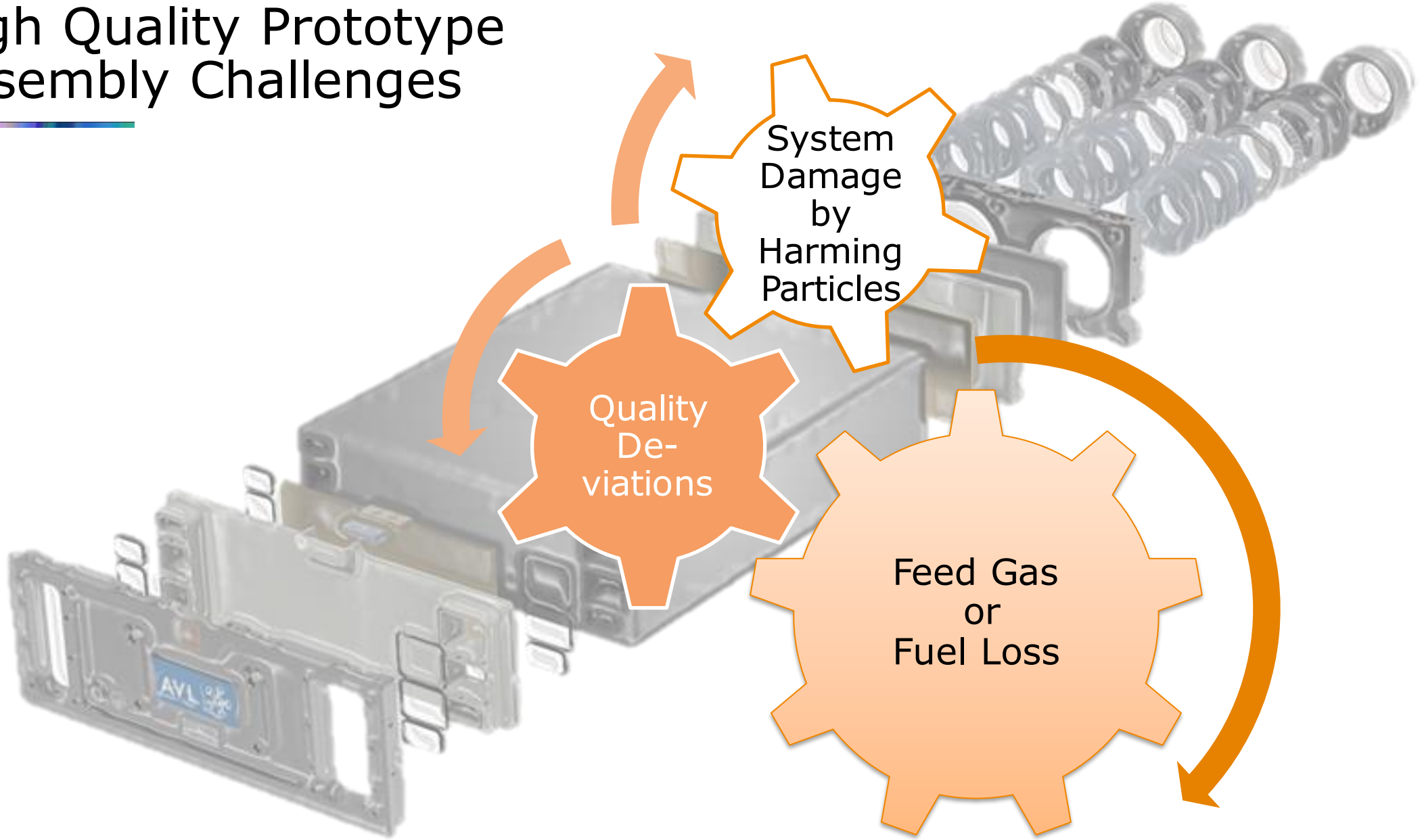
- Checking the quality and quantity
- Parts measurement
- Reaction on quality deviations

- Preparing for UUT Build
- Creation UUT Build documentation
- Handing over the UUT

Content

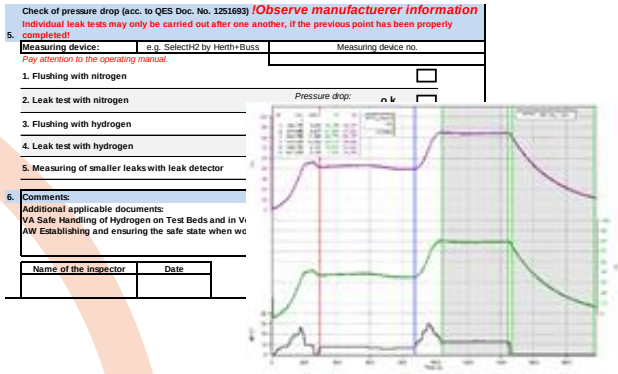

Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

High Quality Prototype Assembly Challenges

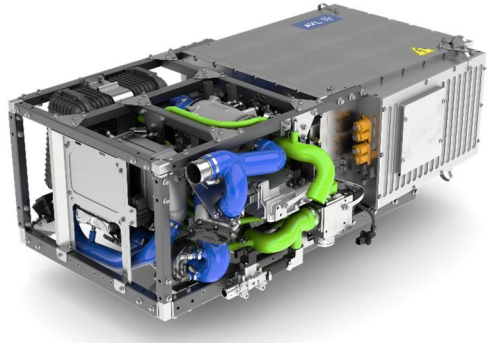


High Quality Prototype Assembly

System pre-check

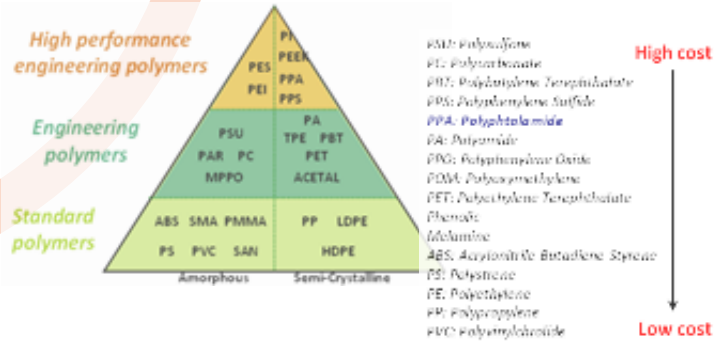


Project parts and consumables



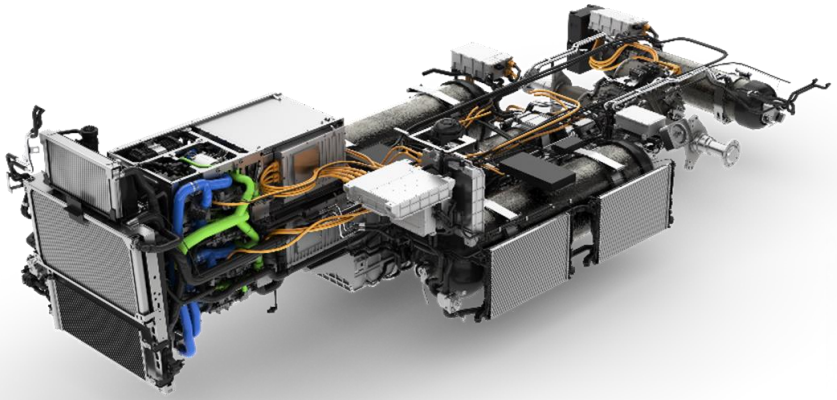
Compatible materials

Parts cleaning



High Quality Prototype Assembly Competences

- Early Prototype build-up
- Fast reaction on design issues
- Train technicians in-house or onsite at customer

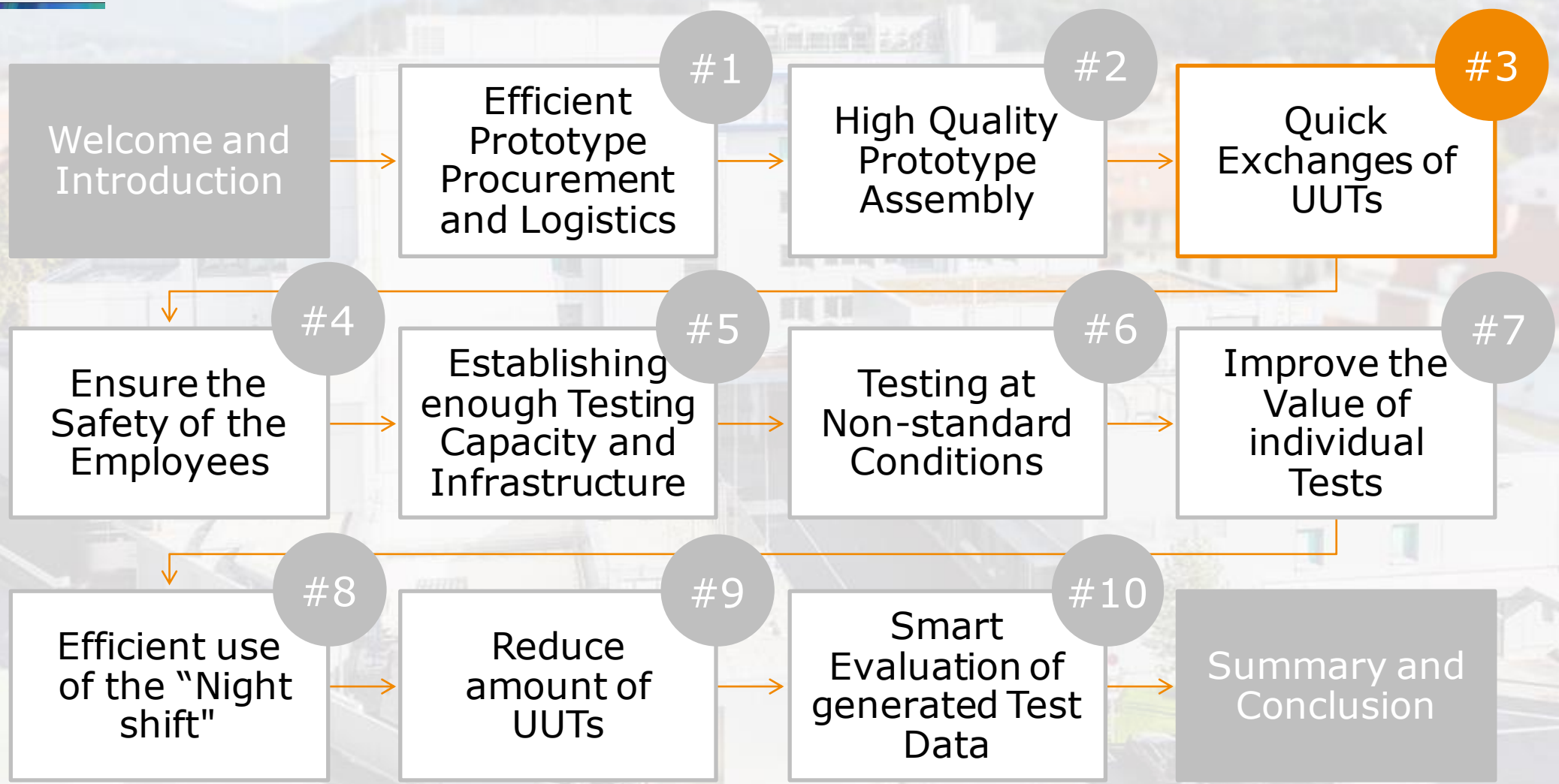


Heavy Duty

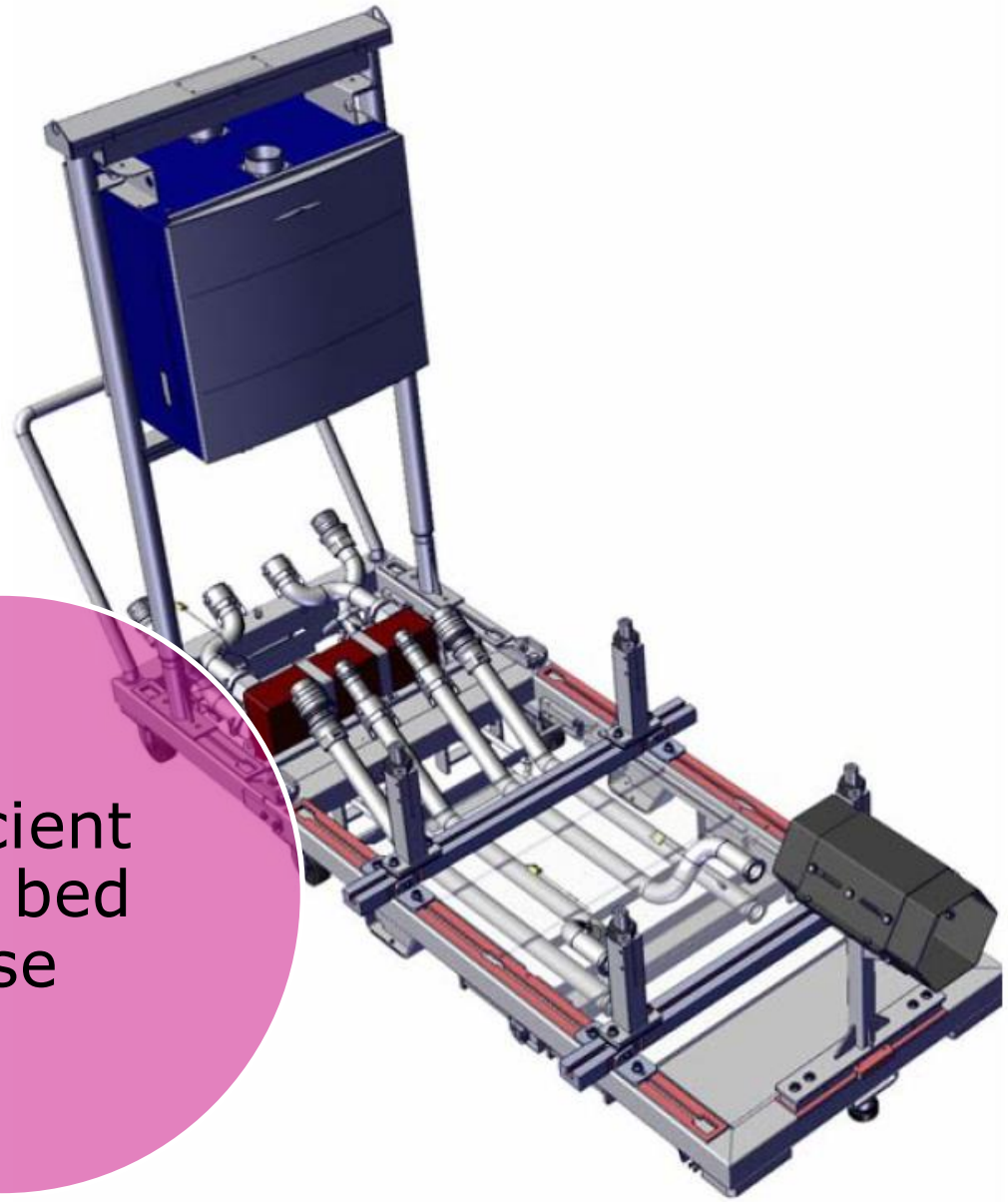
Passenger Car

Stationary

Content


Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

Quick Exchanges of UUTs Challenges



Avoid test bed downtimes

Aligned equipment and interfaces

Efficient test bed use

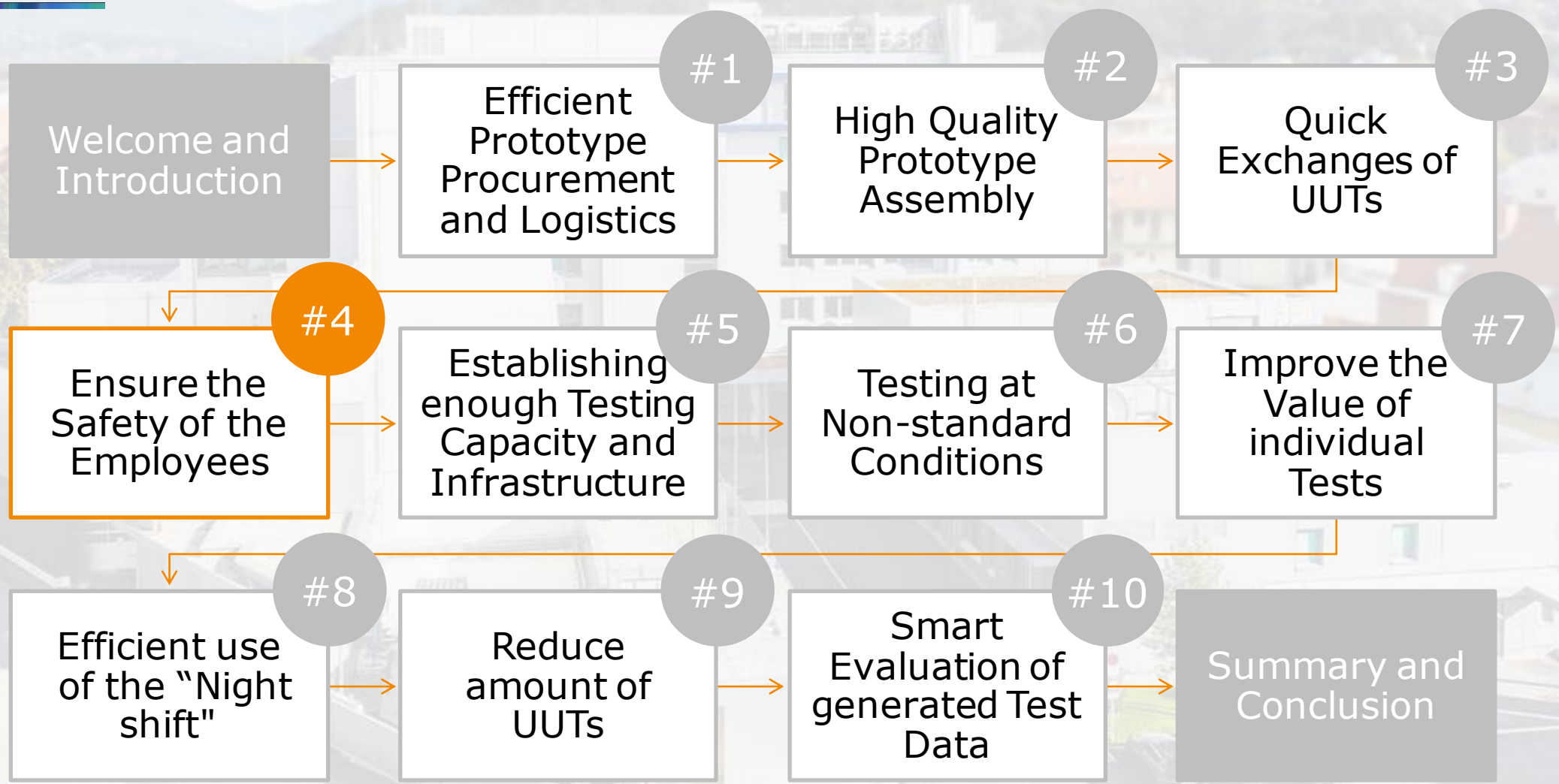
Quick Exchanges of UUTs

- UUT preparation outside of test bed
  - Mechanical and electrical setup on pallet
  - Parametrization and calibration
  - Leak and system check

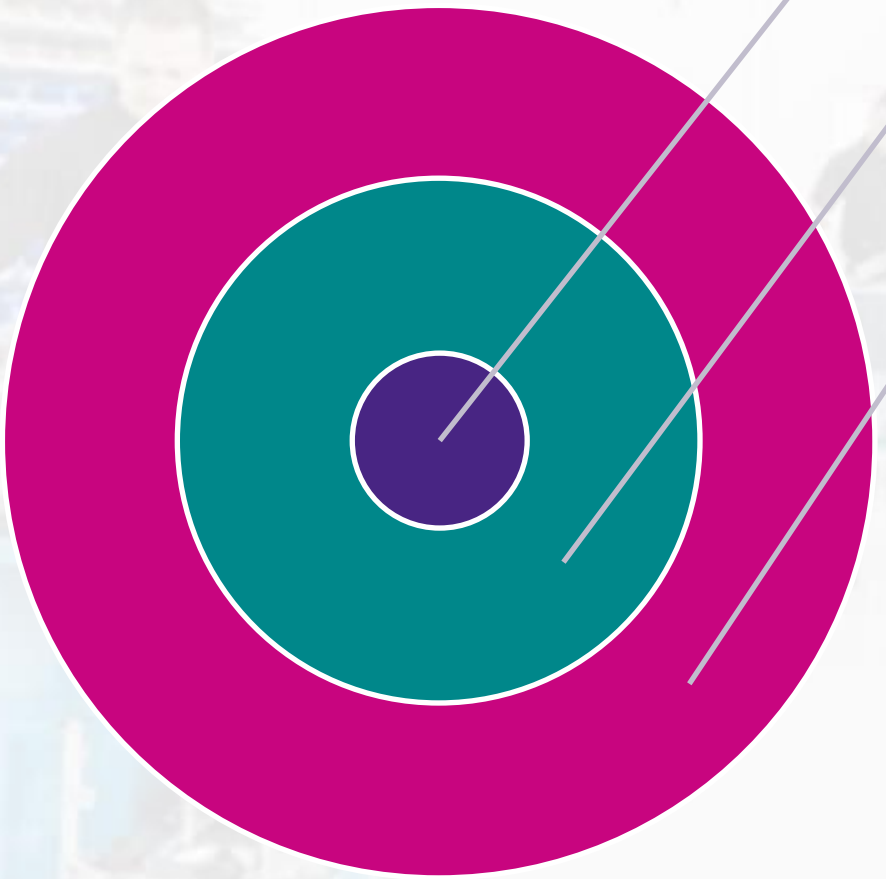
- UUT setup and commissioning on test bed
  - Standardized interfaces
  - Safety and Quality checks

Reduce setup and instrumentation time @ test bed up to 60%

Content


Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

Ensure the Safety of the Employees Challenges



Incidents

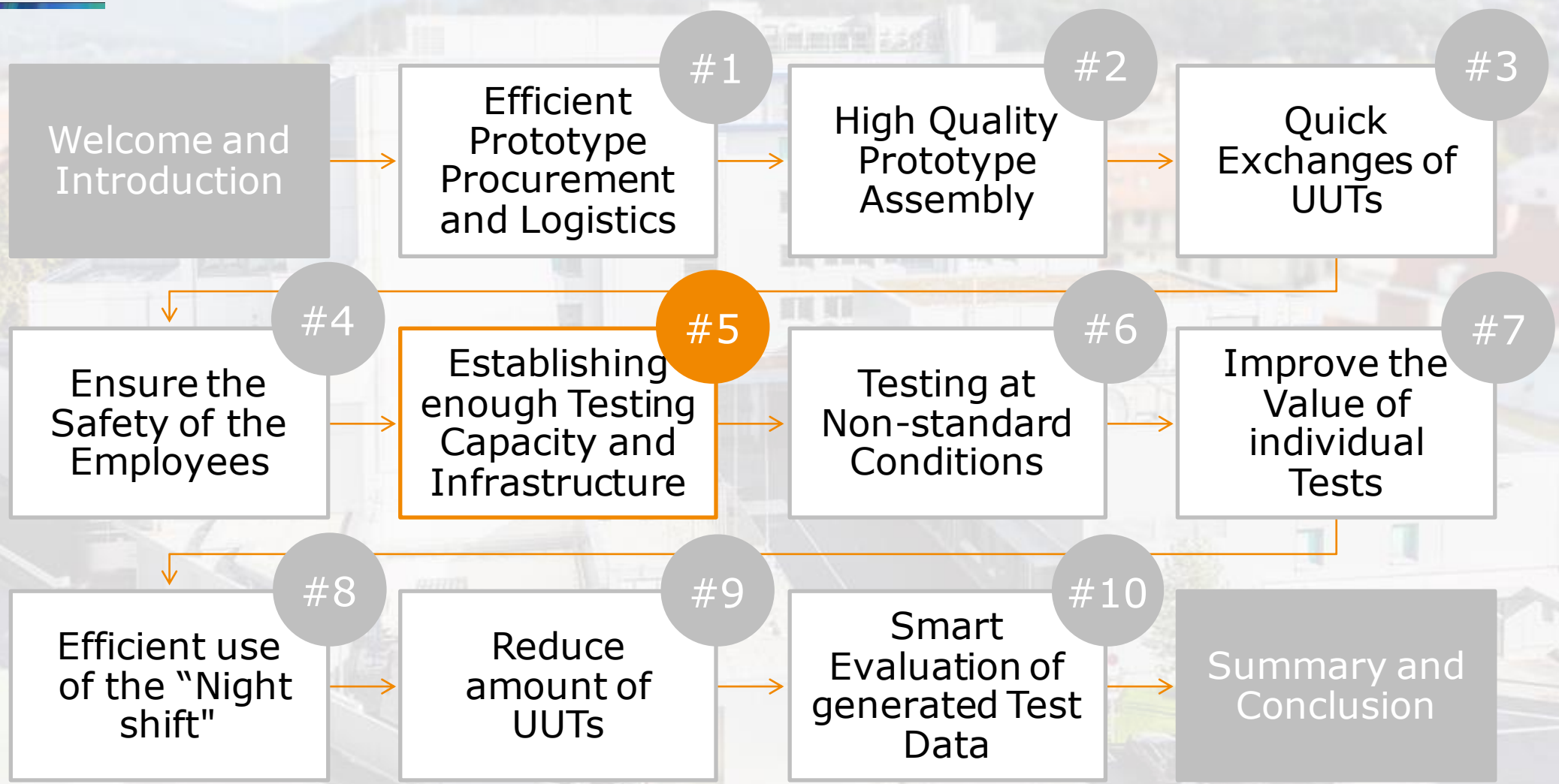
Skills

Staff capacity

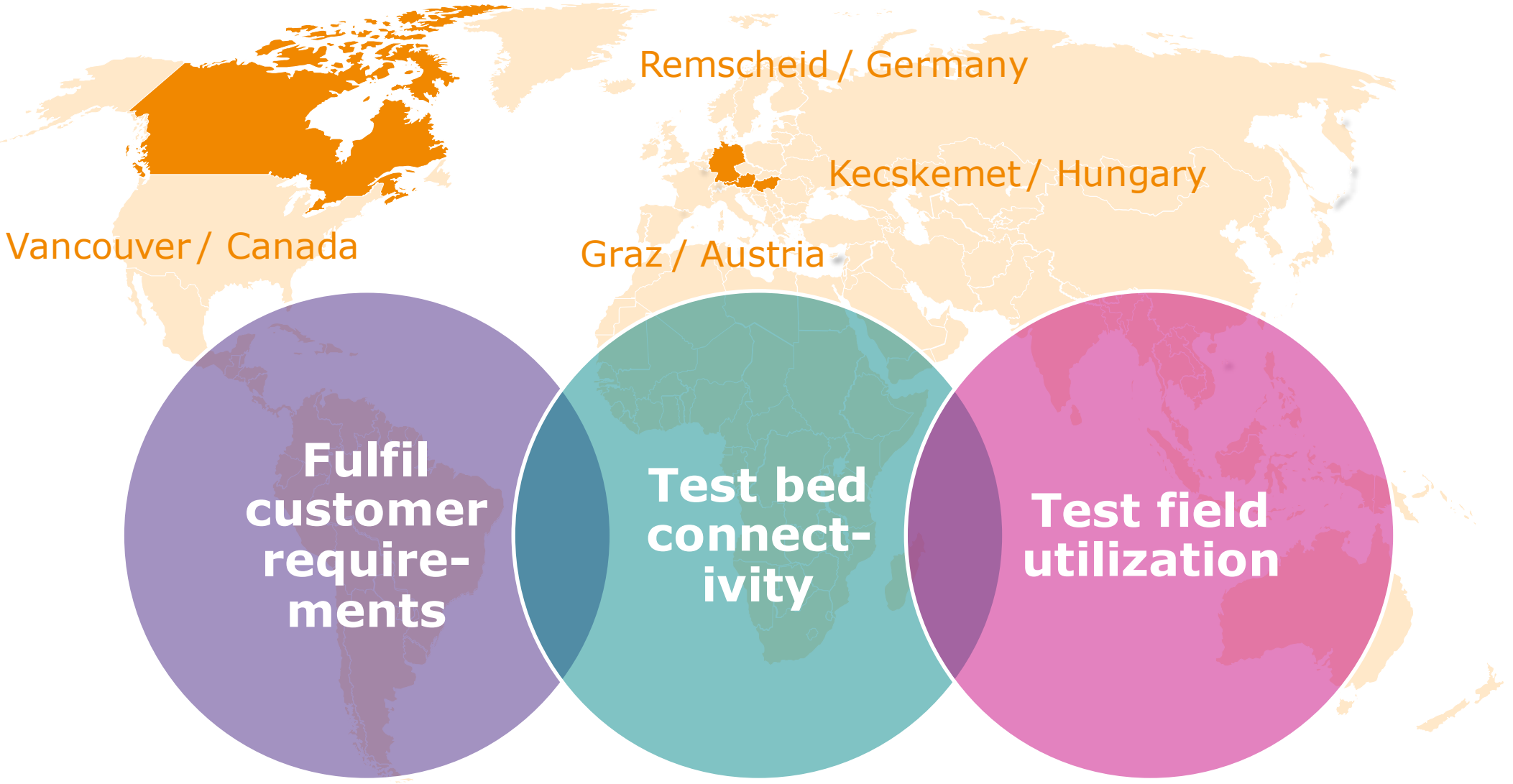
Ensure the Safety of the Employees

- Procedural instructions
  - Safety standards in combination with fuel cell
  - H2 Responsibilities
- Training of Employees
  - Modul based training
  - Fuel Cell handling (training on the job)
- Safety Checks (HV and H2 release)

Content

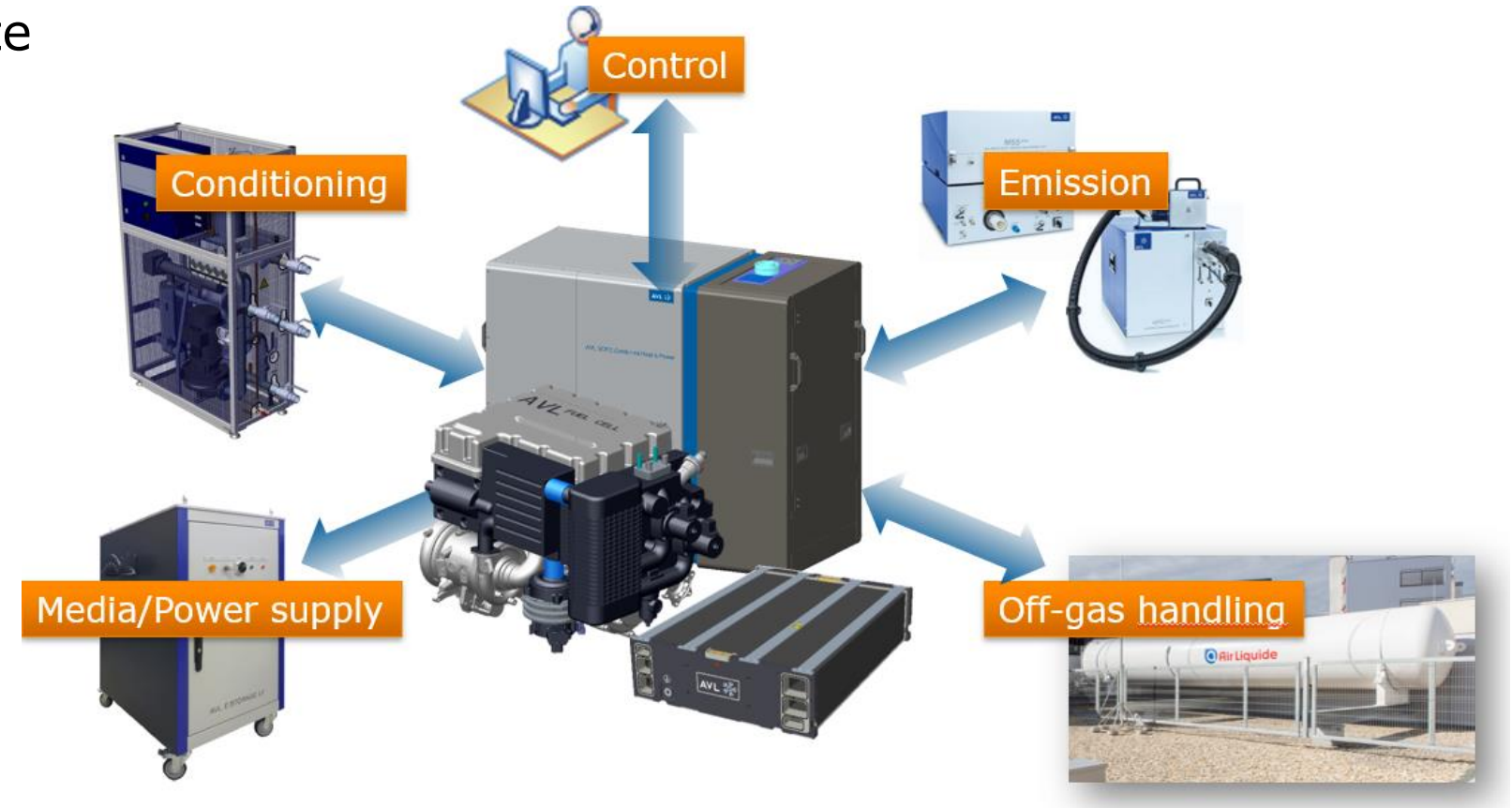

Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

Establishing enough Testing Capacity and Infrastructure Challenges

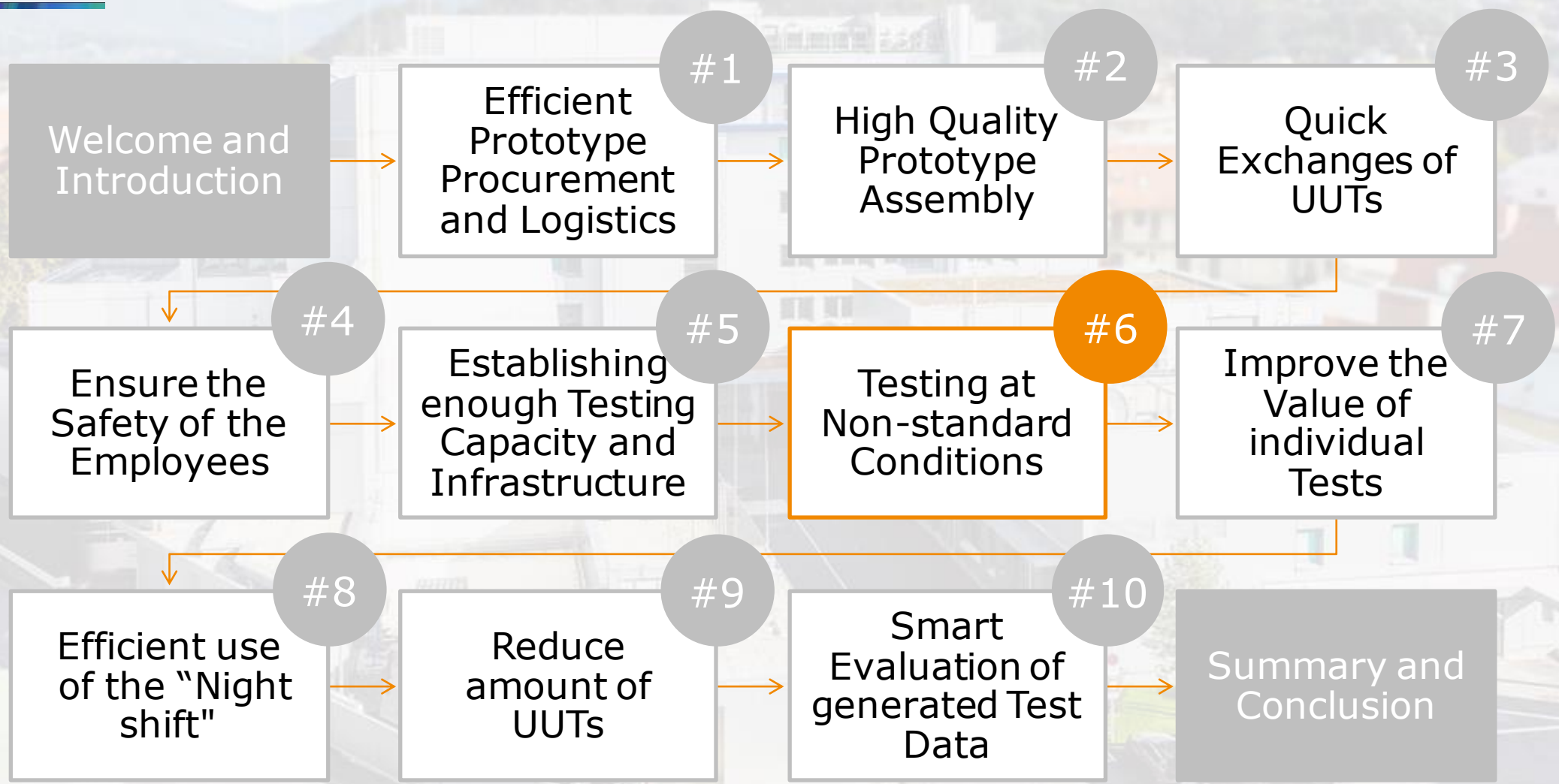


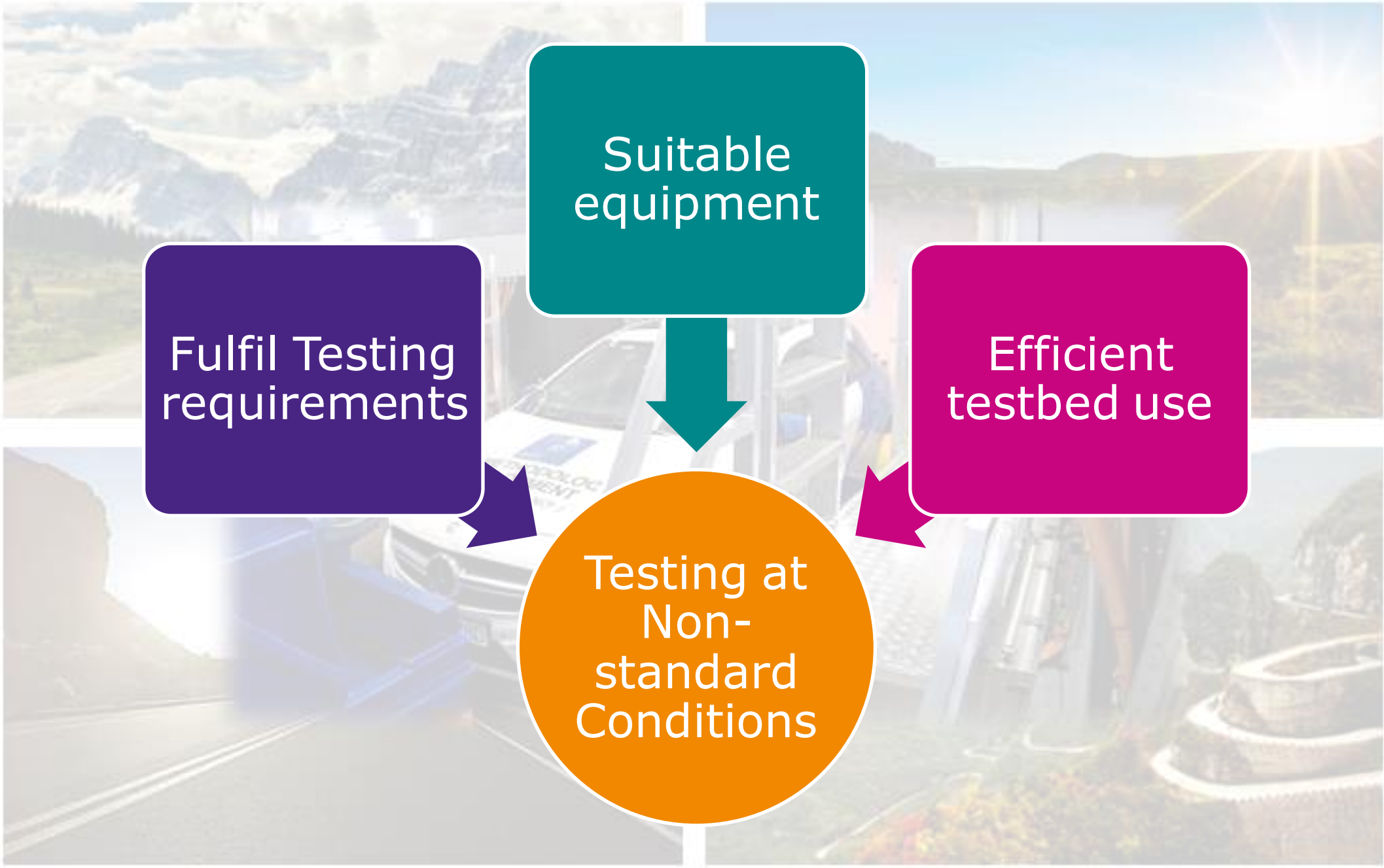
Establishing enough Testing Capacity and Infrastructure

- Variable equip able test field related to customer requirements
- Modular test bed concept starting on system level
- Usage specific hourly rate (test bed equipment)
- Remote Control
- Test bed aligned to AVL pallet system
- Fuel Cell conform supply media



Content

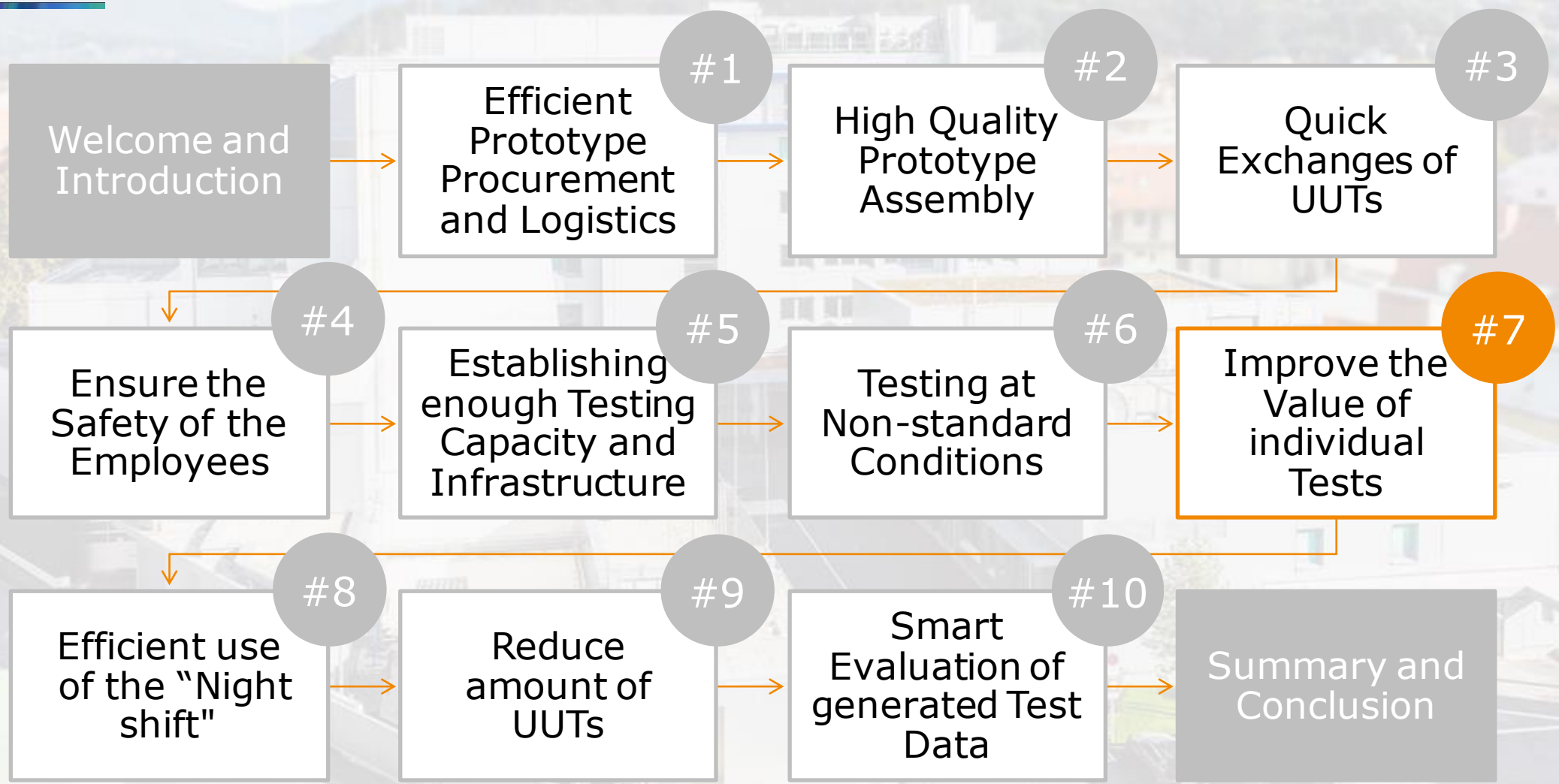

Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion


Suitable equipment
Fulfil Testing requirements
Efficient testbed use
Testing at Non-standard Conditions

Testing at Non-standard Conditions

- Temperature range
  - - 40 °C up to + 60 °C
  - Altitude range from sea level (0 m) up to 5000 m
- Test bed aligned to AVL pallet system
  - Fast change between test bed A and B
  - Test program aligned use of test bed

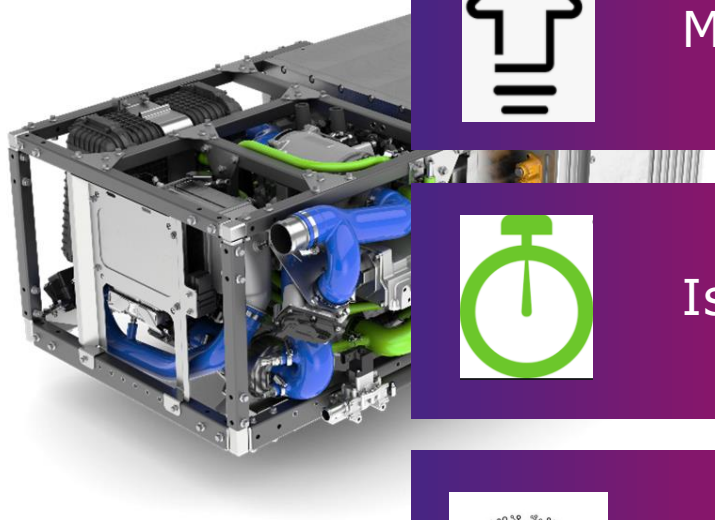
Content


Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

Improve the Value of individual Tests Challenge

Calibration task: Steady state system efficiency maximization

- Current
- Coolant Temperature Inlet
- Temperature Delta
- Inlet Humidity
- Inlet Pressure
- Cathode Stoichiometry
- Membrane difference pressure



Manual calibration: ~4 weeks

Maximize!

Is there a quicker way?

Keep below limit

Keep below limit

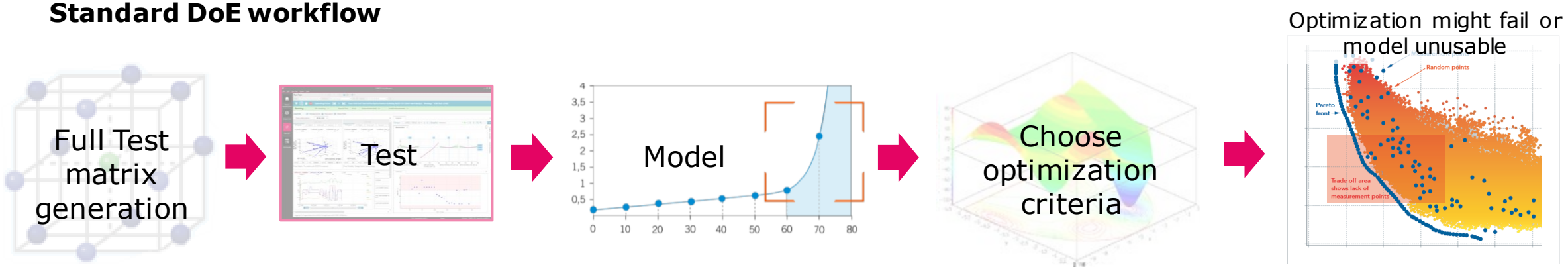
Is there a smarter way?

Improve the Value of individual Tests Solution

Traditional DoE

- Test – Model – Predict – Optimize: Too late for knowledge gained after testing to improve the testing phase

Standard DoE workflow



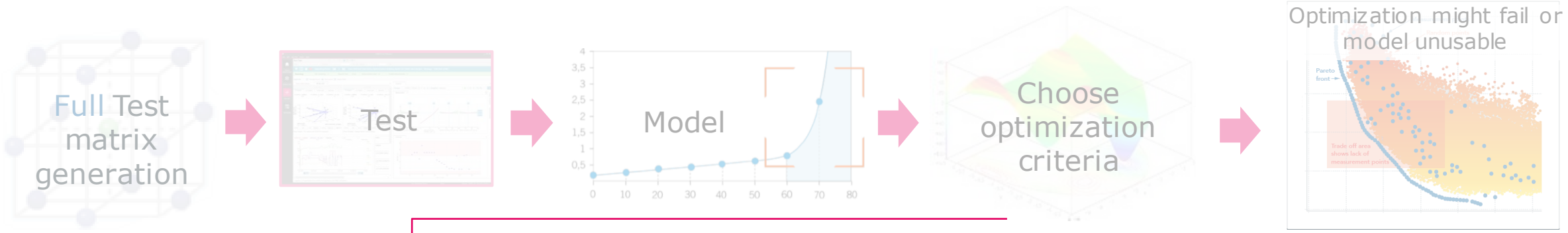
For high numbers of input dimensions or highly non-linear systems, even standard DoE has it's limits

Improve the Value of individual Tests Solution

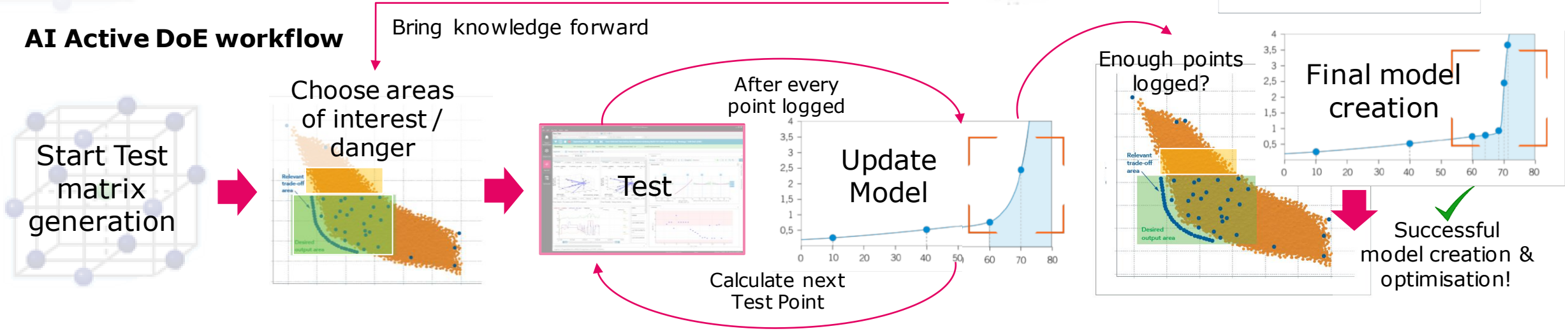
Active DoE

- Model and Predict *during* the test: Bring Knowledge forward to the testing phase

Standard DoE workflow



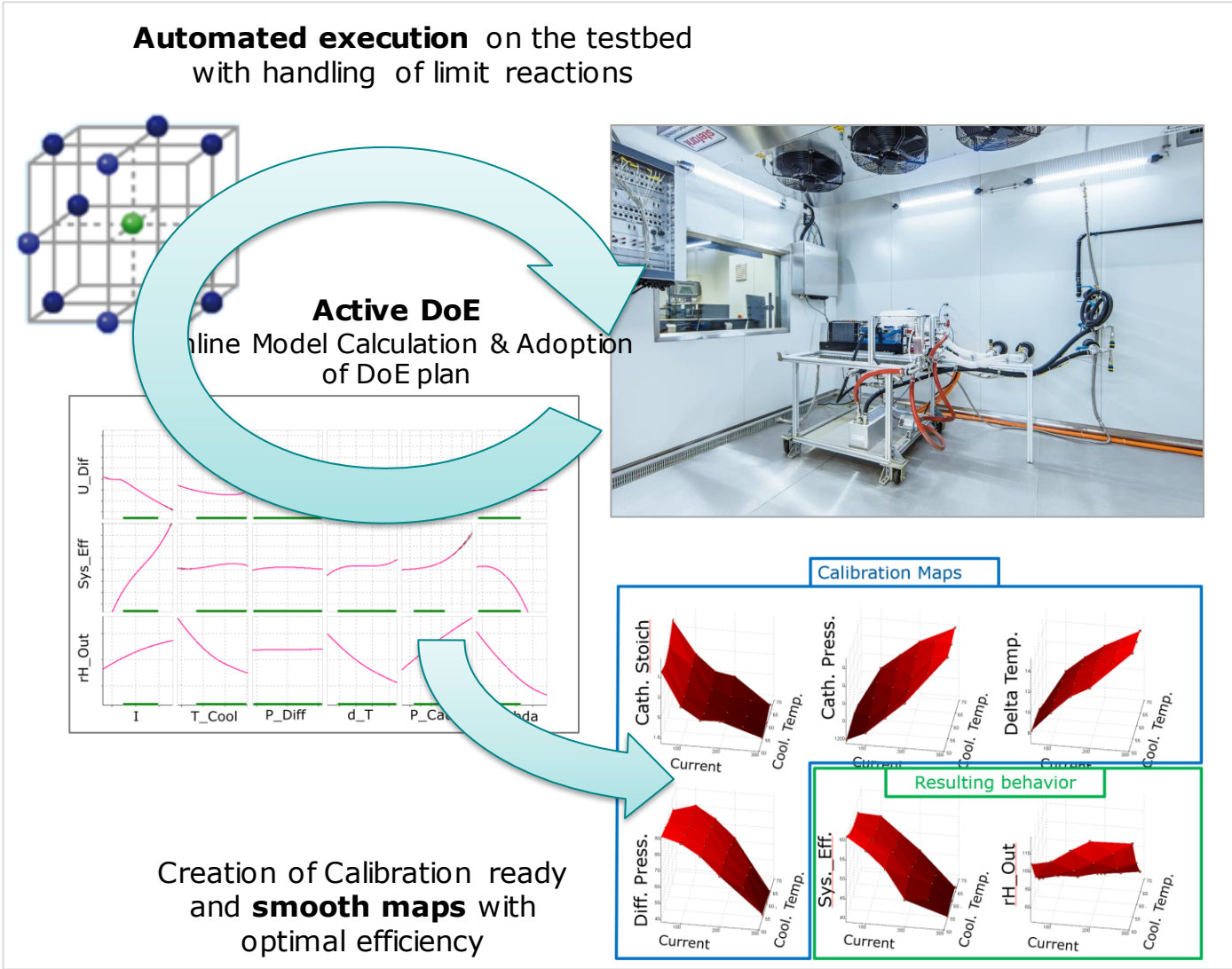
AI Active DoE workflow



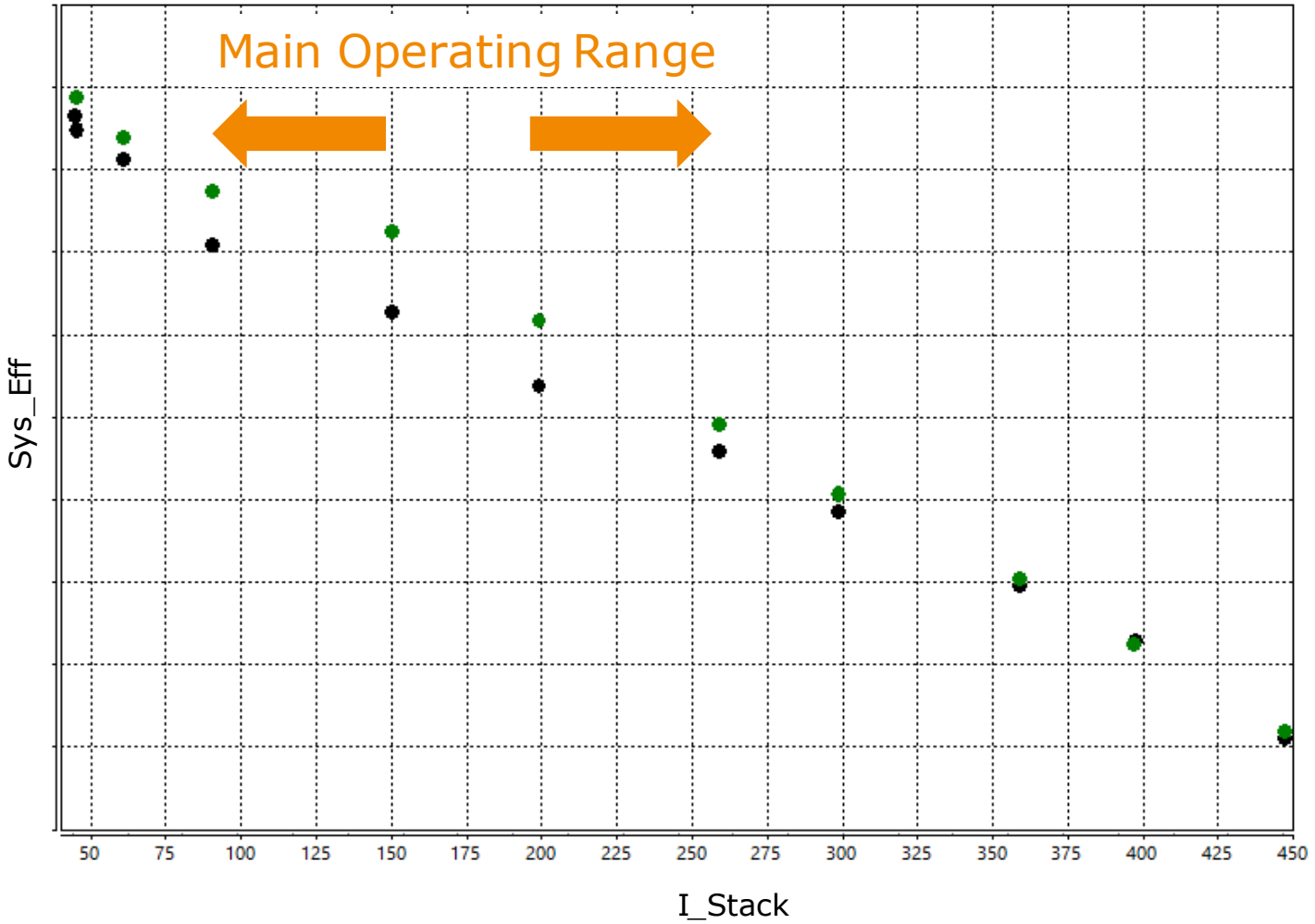
Improve the Value of individual Tests Solution

CAMEO Solution

- **Minimized** testing effort by measuring only relevant variations with Active DoE
  - **Active DoE** decides which variations to perform based on self-learning models during the automated test run
- **AI models** allow for fast and easy cognition of the system behavior and its influences
- Optimization algorithm finds the **optimum calibration** considering constraints and delivering **smooth** FCCU **maps** at the same time



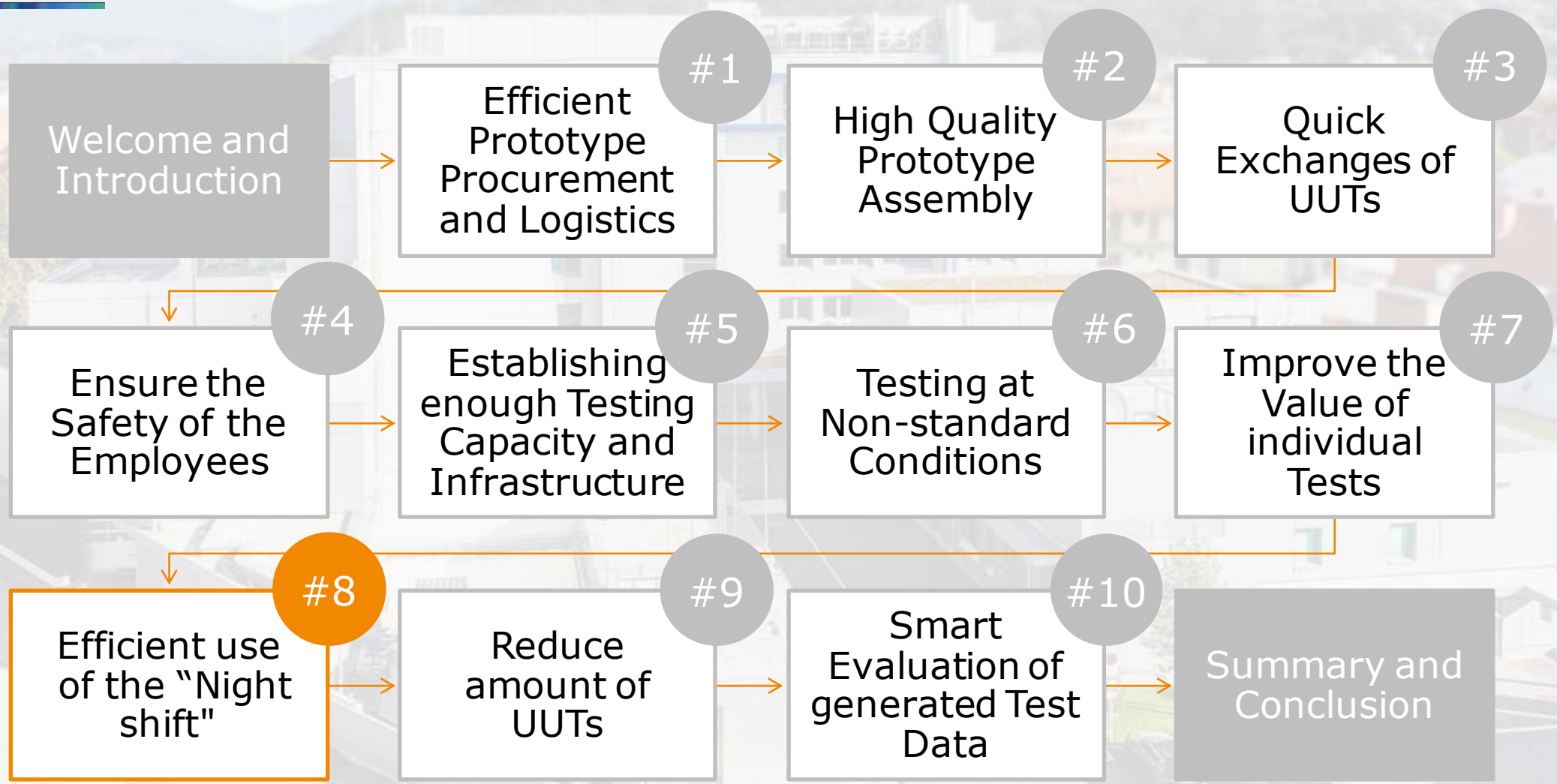
Improve the Value of individual Tests Solution



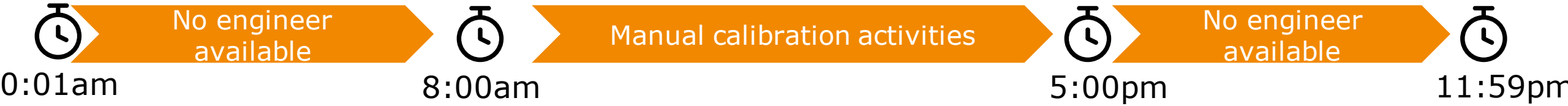
Back: Baseline
Green: After Optimization

- Each load point shows an improved efficiency
- At ~150A, the **efficiency is increased by 4%**.
- Effort: **~50h runtime**, mainly nights and weekends.
- Reduction of >75% compared to manual approach

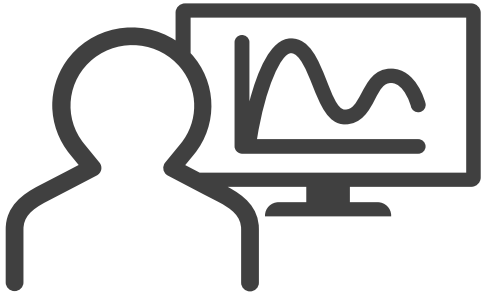
Content


Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

Efficient use of the “Night shift” Challenge



Testbed not utilized ☹



Testbed utilized ☺

Testbed not utilized ☹

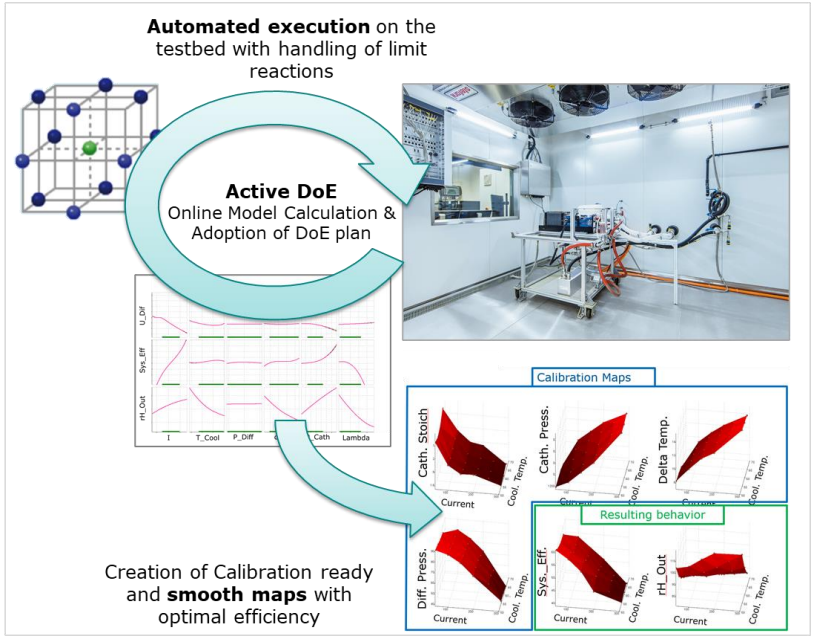
Efficient use of the “Night shift” Solution

Automatic execution of Active DoE — 0:01am

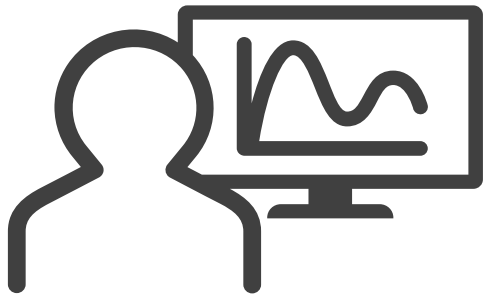
Manual calibration activities — 8:00am

Automatic V-I-Curve — 5:00pm

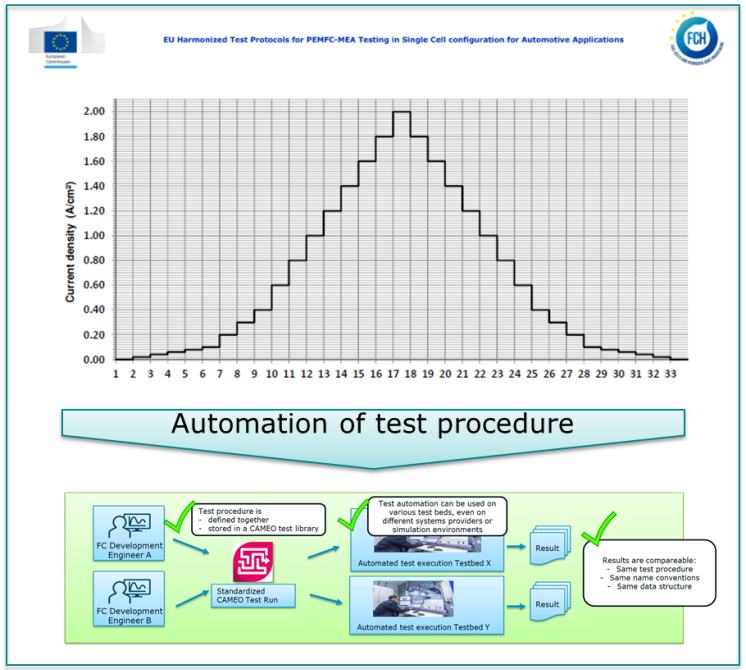
11:59pm



Testbed utilized ☺

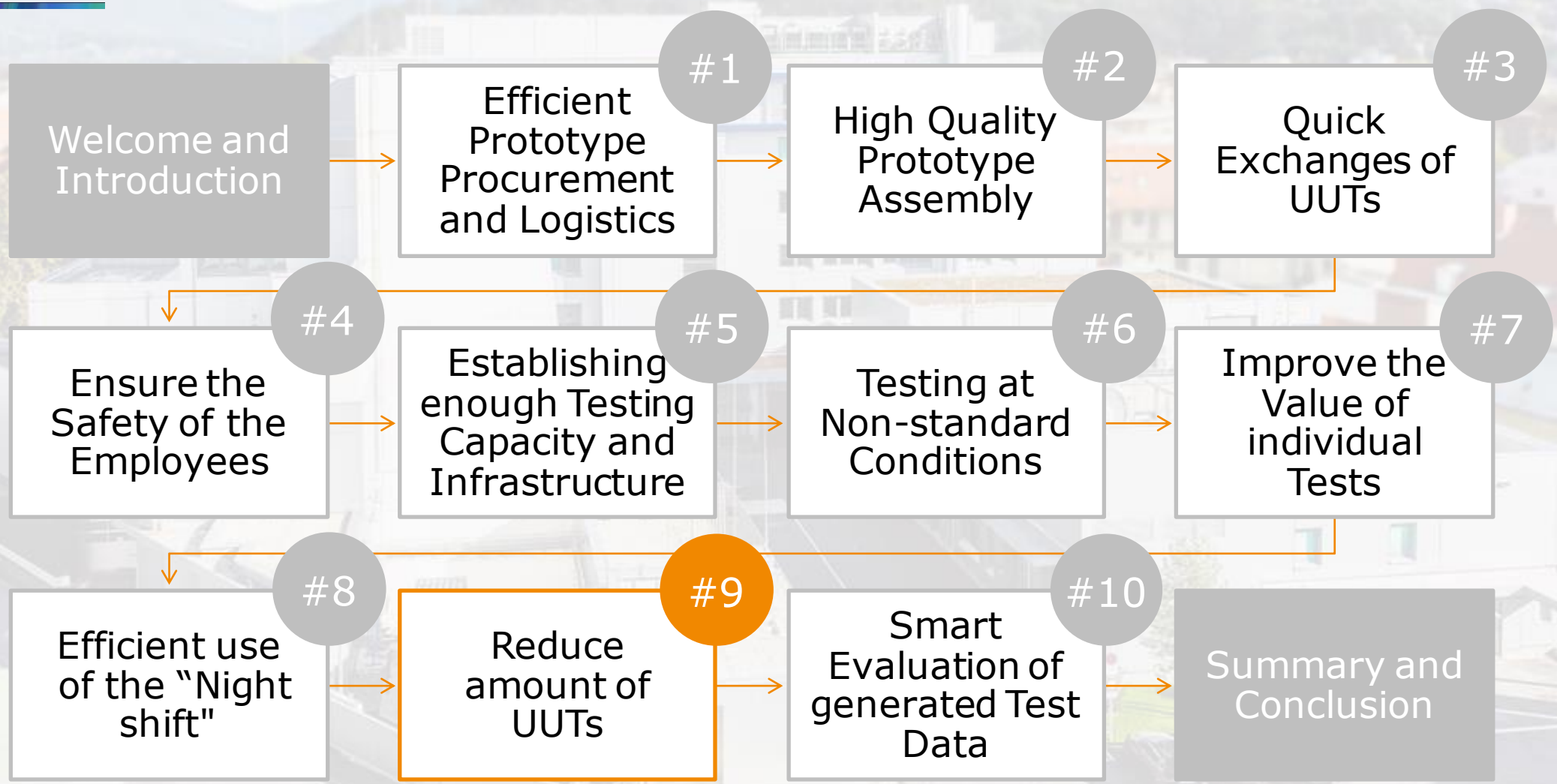


Testbed utilized ☺



Testbed utilized ☺

Content

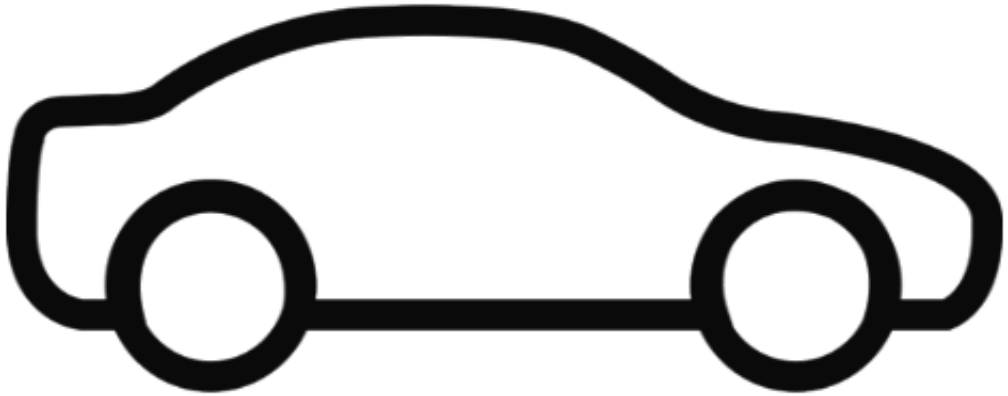

Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

Reduce Amount of UUTs Challenge

Physical Testing

Testbed

Prototype System

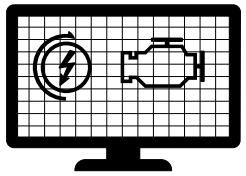


Prototype Vehicle

Reduce Amount of UUTs Solution

Virtual Testing

Physical Testing



Office Simulation

Virtual Testbed

Testbed

Prototype System

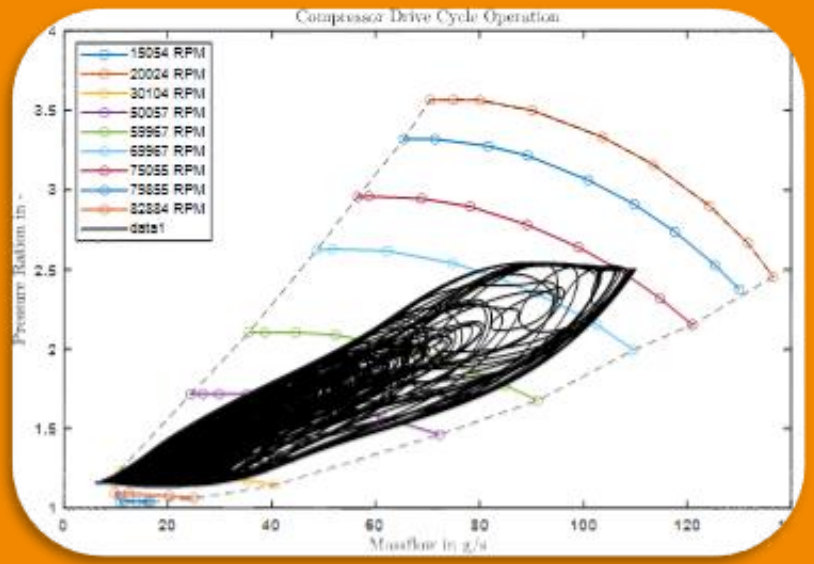
Prototype Vehicle

Reduce Amount of UUTs Solution

Virtual Testing in Design Phase

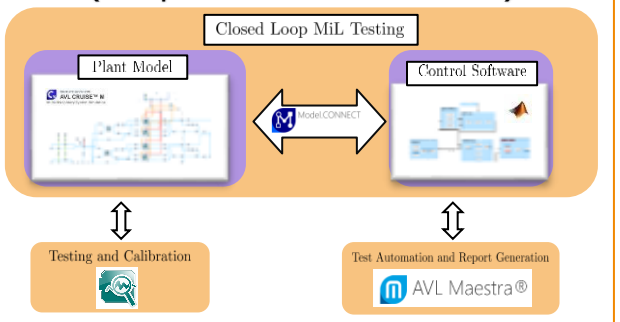
Virtual Testing in Calibration Validation Phase

Component Operation



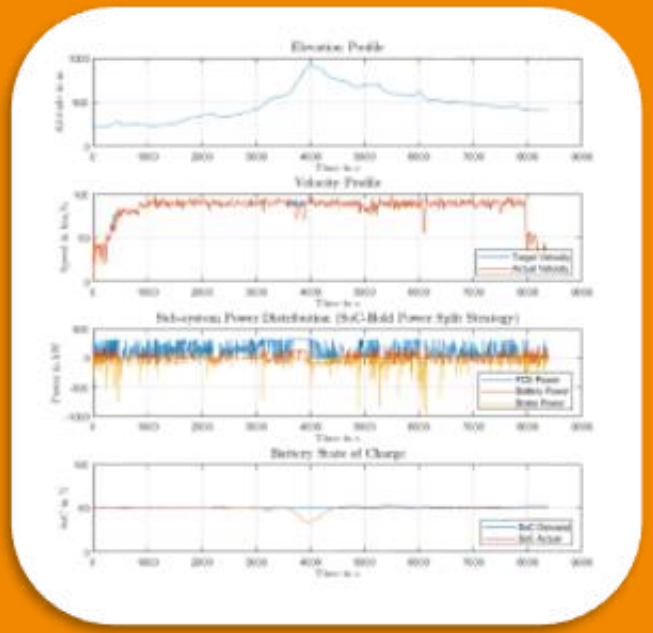
FC-System Simulation

(coupled MiL Environment)

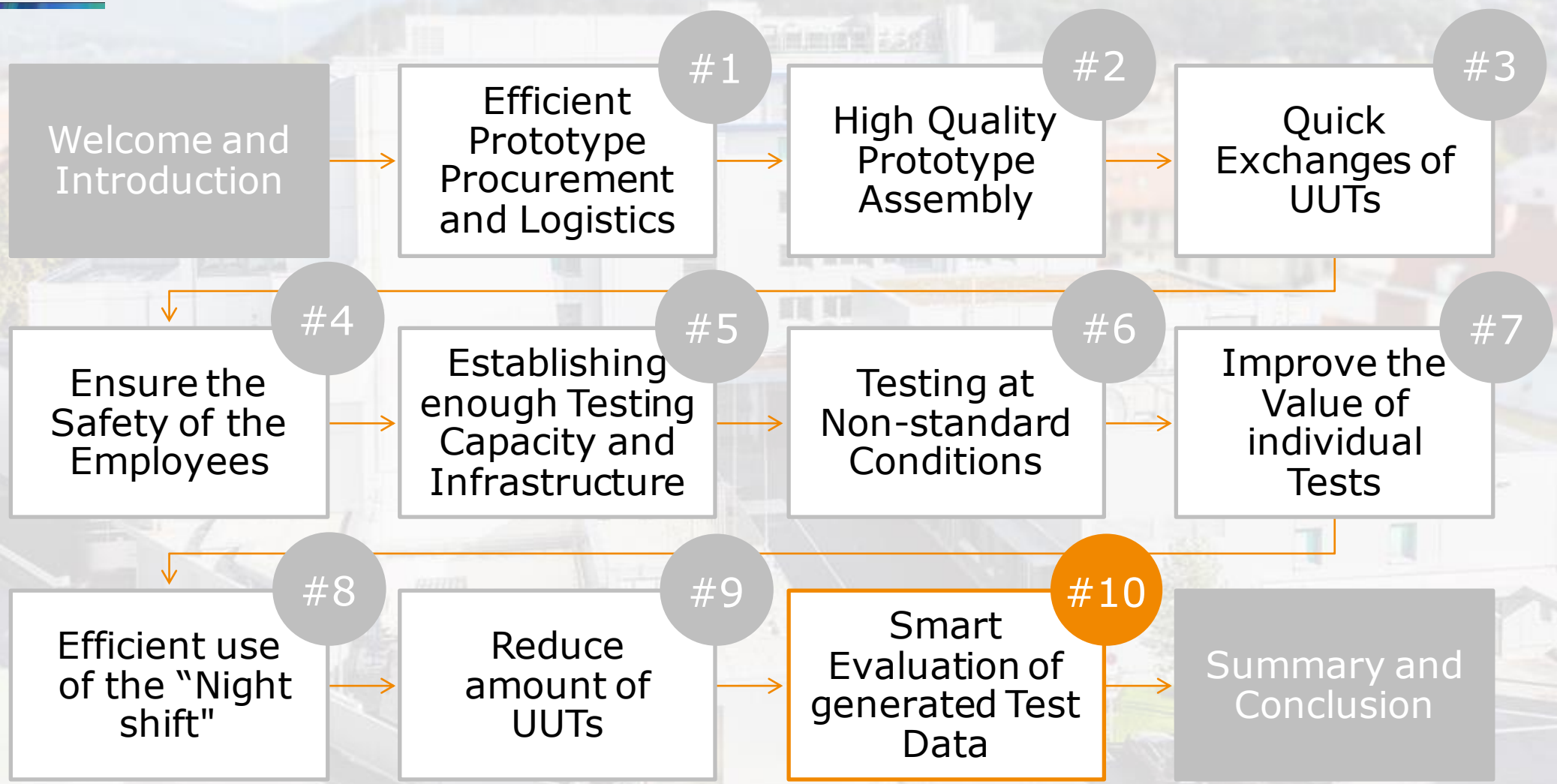


Vehicle Simulation

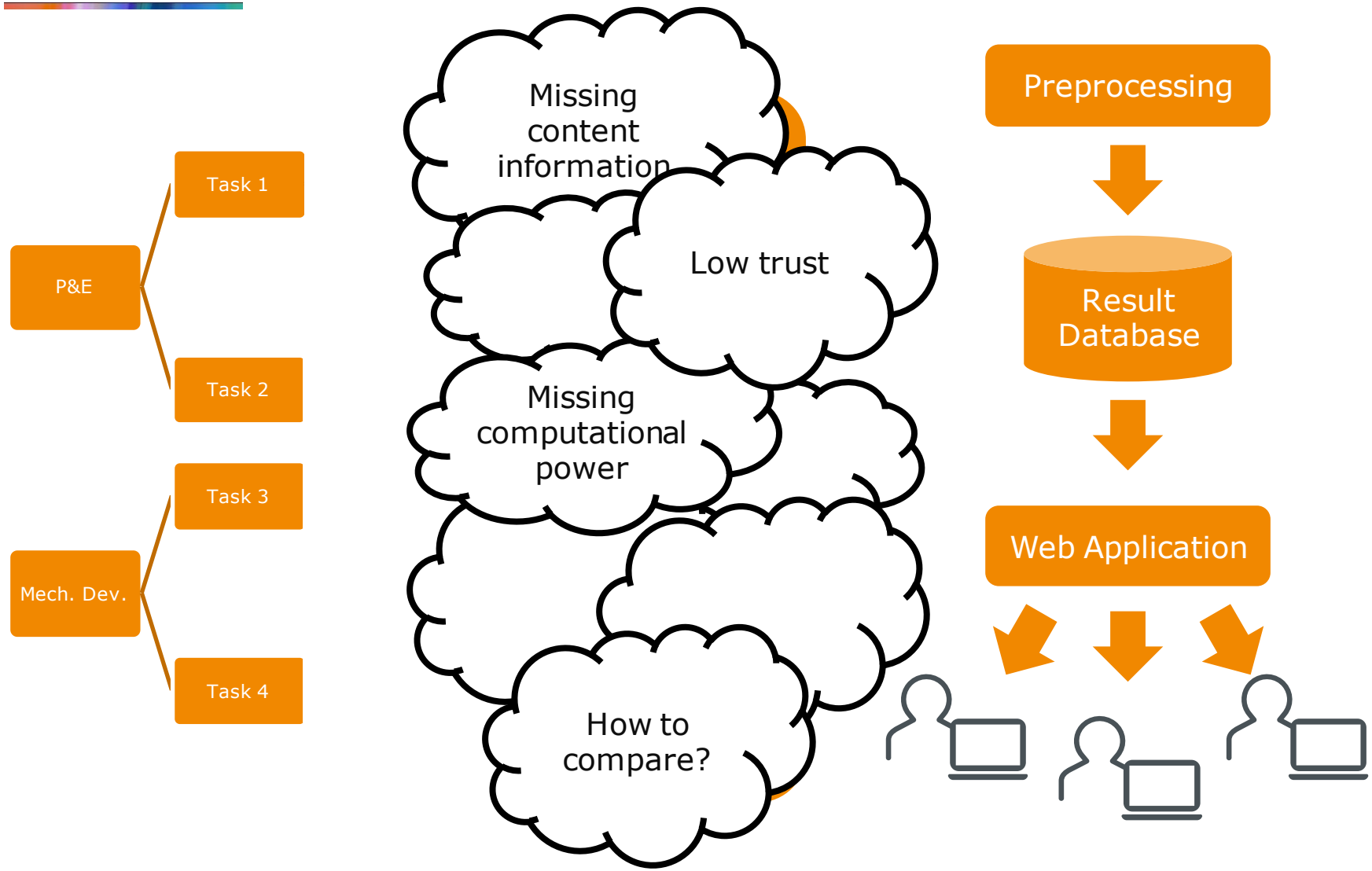
(Drive-Cycle from Vienna to Graz)



Content


Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

Smart Evaluation of generated Test Data via “Event-driven Big Data Analytics”

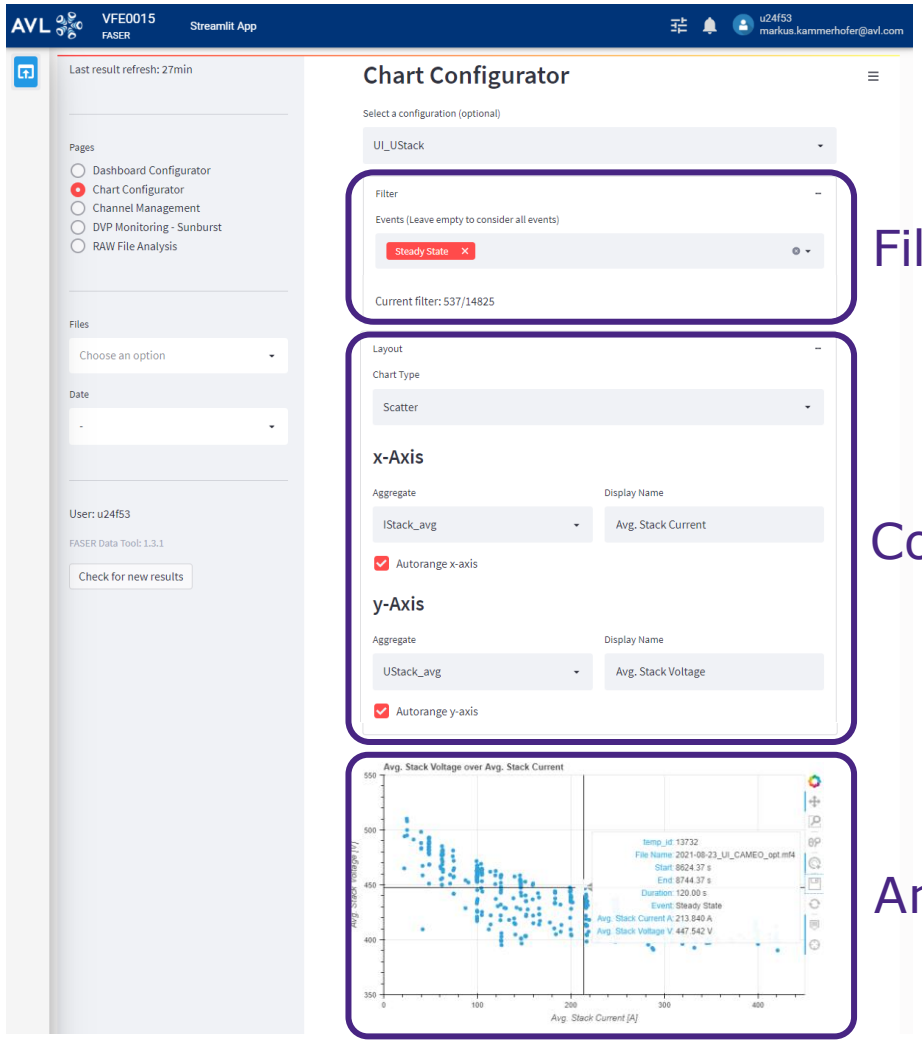


Example
669 measurements
196GB/176h

Extracting …
… 14.825 events
… 2.591 aggregates
… ~38 Mio. results

in 20mins!

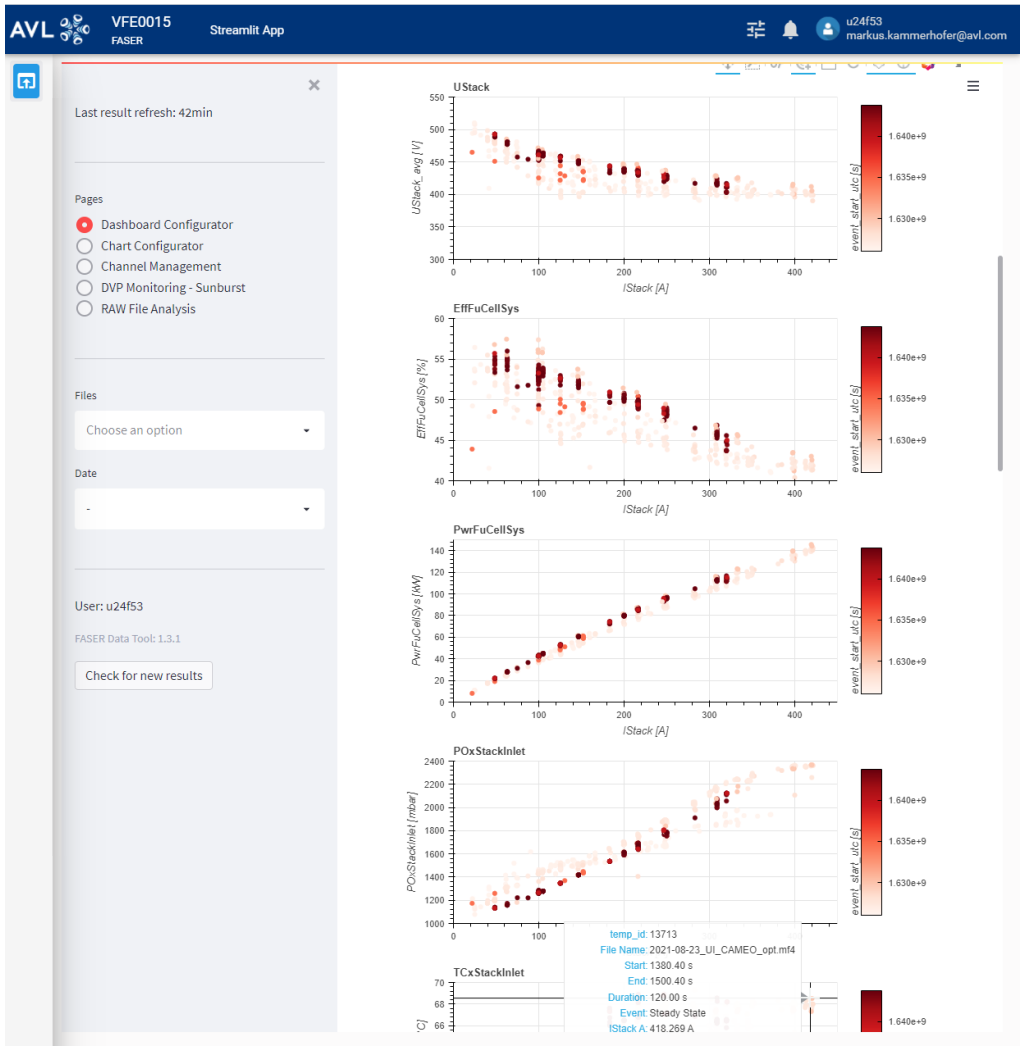
Exploration with the interactive Chart and Dashboard Configurators



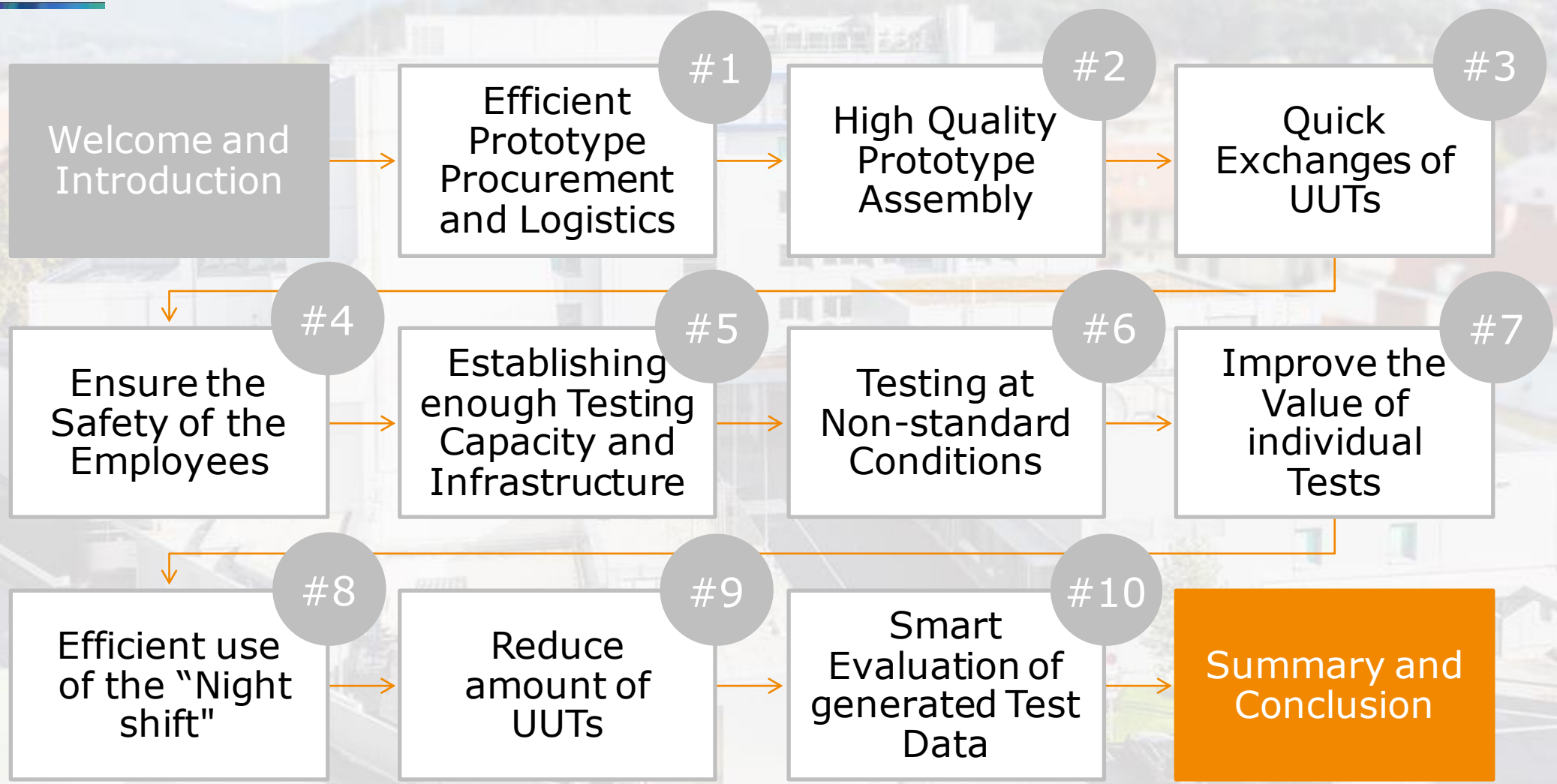
Filter

Configure

Analyze



Content


Welcome and Introduction
#1
Efficient Prototype Procurement and Logistics
#2
High Quality Prototype Assembly
#3
Quick Exchanges of UUTs
#4
Ensure the Safety of the Employees
#5
Establishing enough Testing Capacity and Infrastructure
#6
Testing at Non-standard Conditions
#7
Improve the Value of individual Tests
#8
Efficient use of the "Night shift"
#9
Reduce amount of UUTs
#10
Smart Evaluation of generated Test Data
Summary and Conclusion

Key topics and takeaways

Optimize testbed efficiency, performance and safety

Maximise the value of individual tests

Establish flexible testing infrastructure

How to solve the ten most significant fuel cell and electrolyzer testing challenges

Q&A

Public

Contact

LOCATION

AVL List GmbH
Hans-List-Platz 1
8020 Graz
Austria

PHONE

+43 316 787 7014
+43 316 787 1543
+43 316 787 2700
+43 316 787 8981

EMAIL

christoph.supper@avl.com
Horst.Kiegerl@avl.com
Stefan.Scheidel@avl.com
Markus.Kammerhofer@avl.com

WEBSITE

www.avl.com

Thank you

www.avl.com