(LT-) PEM Fuel Cells
Technology, Potential Hazards and Safety Measures

Stefan Bohatsch
Certification Roadmap of H2 Technologies
EASA, Köln - 2024-12-17

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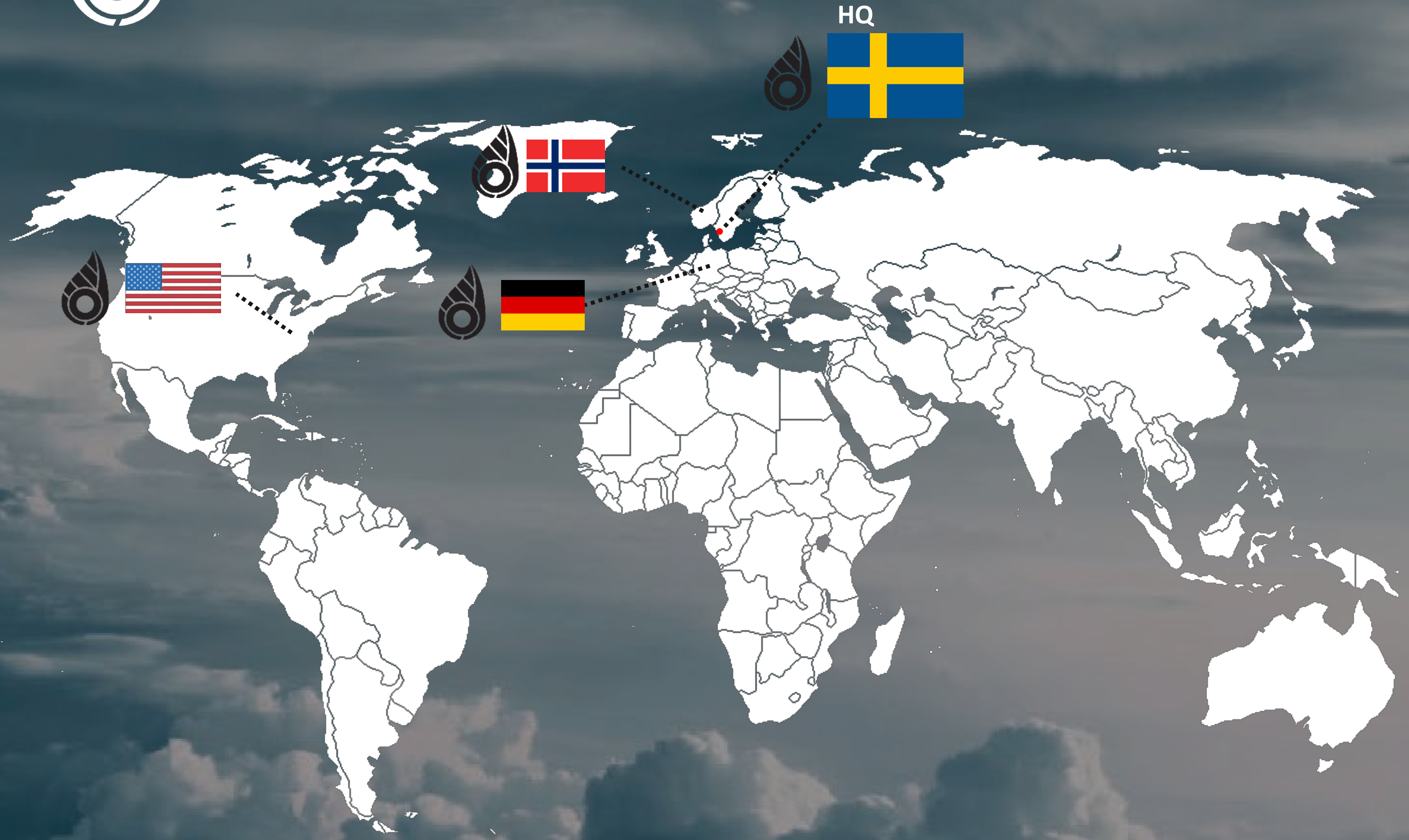


Leading Fuel Cell technology built on 25 years of R&D & IP

Spin-out from the Volvo Group in 2009

Listed on NASDAQ since 2014

HQ in Sweden with global presence
Planned establishments in UK & US

Strategic partners & customers to drive business

Marine

- Passenger
- Fast Ferries
- Cargo Vessels
- Large Yachts

Stationary

- Prime Power
- Back-up Power
- Peak Shaving
- Shore Power

Aviation

- Small Aircraft
  eVTOL
  Helicopters
- Passenger planes
- Drones

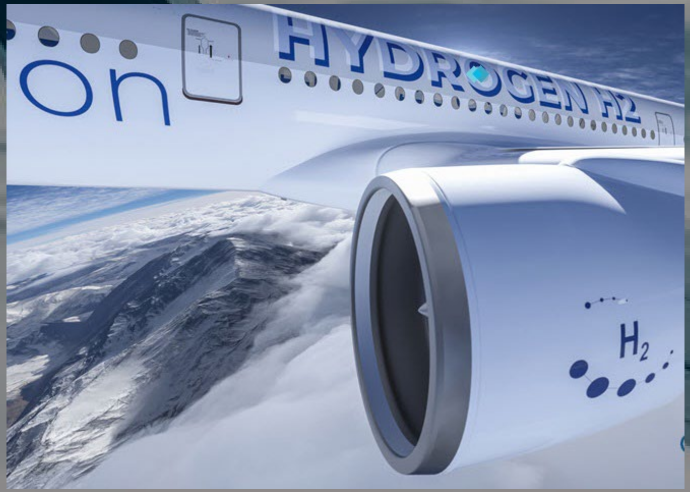
Off-Road

- Material Handling
- Mining Equipment
- Agricultural
- Construction

On-road

BOSCH
Invented for life

Aviation



100 - 300 kW

400 - 1200 kW

1 - 10 MW

Fuel Cell Applications

Marine


3.2 MW Liquid H_2


1.8 MW Ref MeOH


2 x 6.4 MW Comp H_2

Stationary


5 kW mobile


200 – 600 kW mobile


1-2 MW stationary

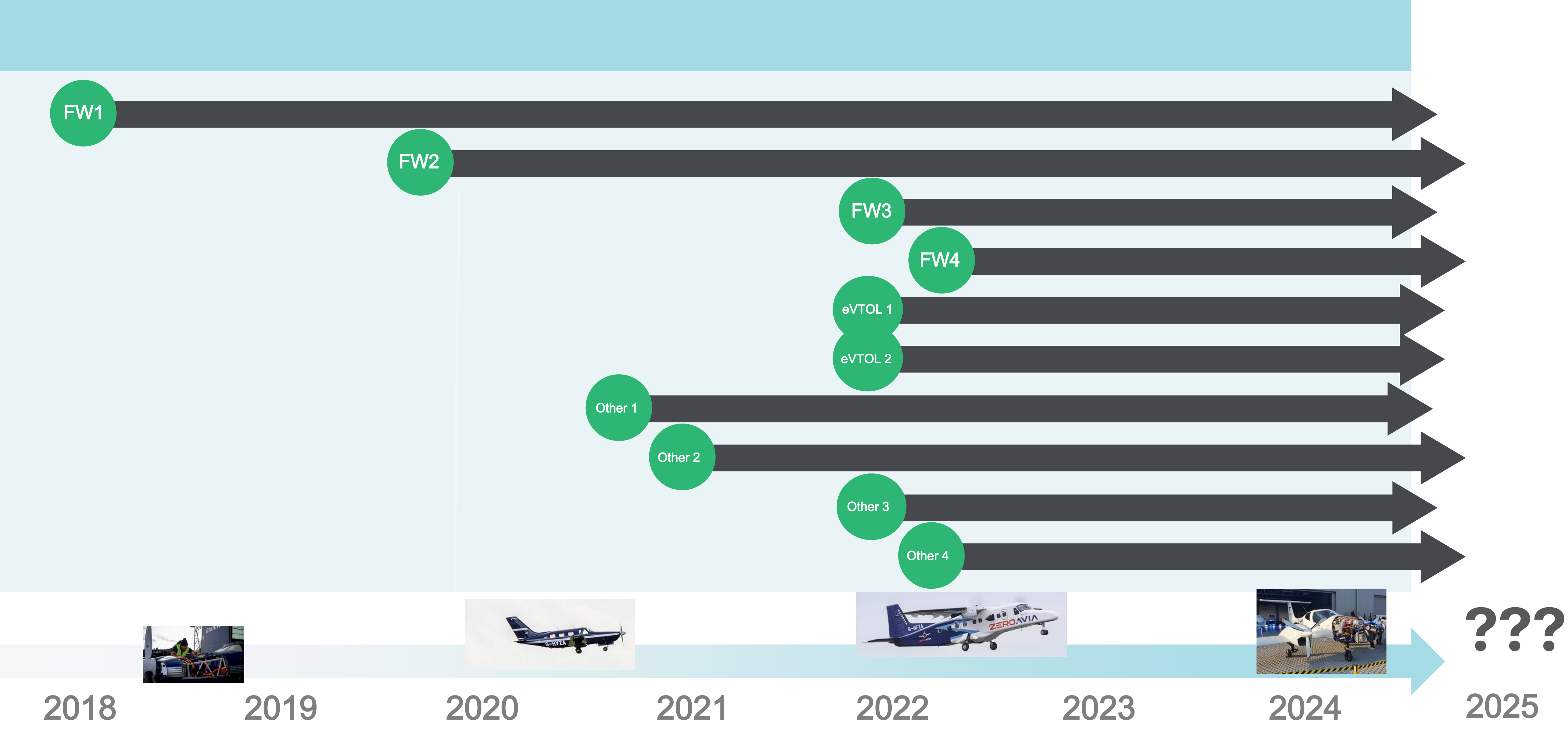
Mobile


100 kW


100 kW


60 kW

PowerCell Aviation Projects



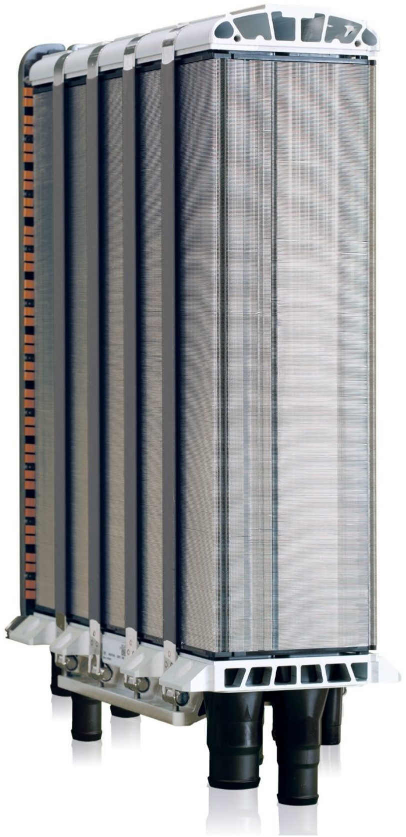
Fuel Cell Stacks

Industrialized Products

25 years of experience with metal bi-polar plate stacks

V-Stack
30 kW / 1kW/kg
H2 from Diesel reforming

P10-Stack
up to 130 kW / 3 kW/kg
Clean H2



MegaWatt
Up 300 kW / 5kW/kg
(Newborn)

CLEAN AVIATION NEWBORN

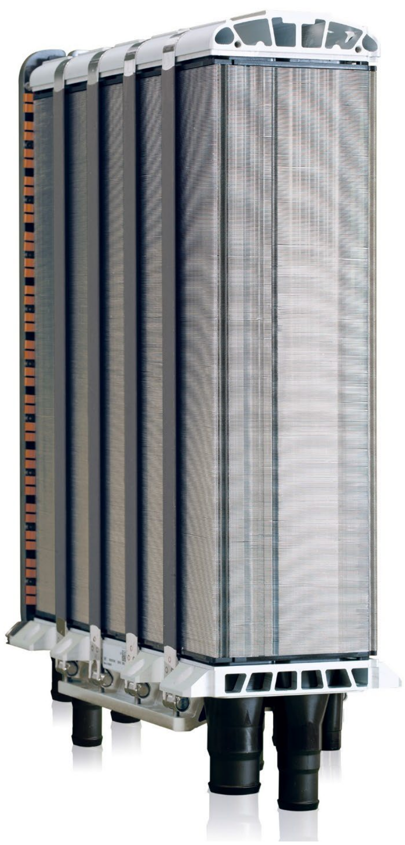
Grant Agreement No. 10 110 1967

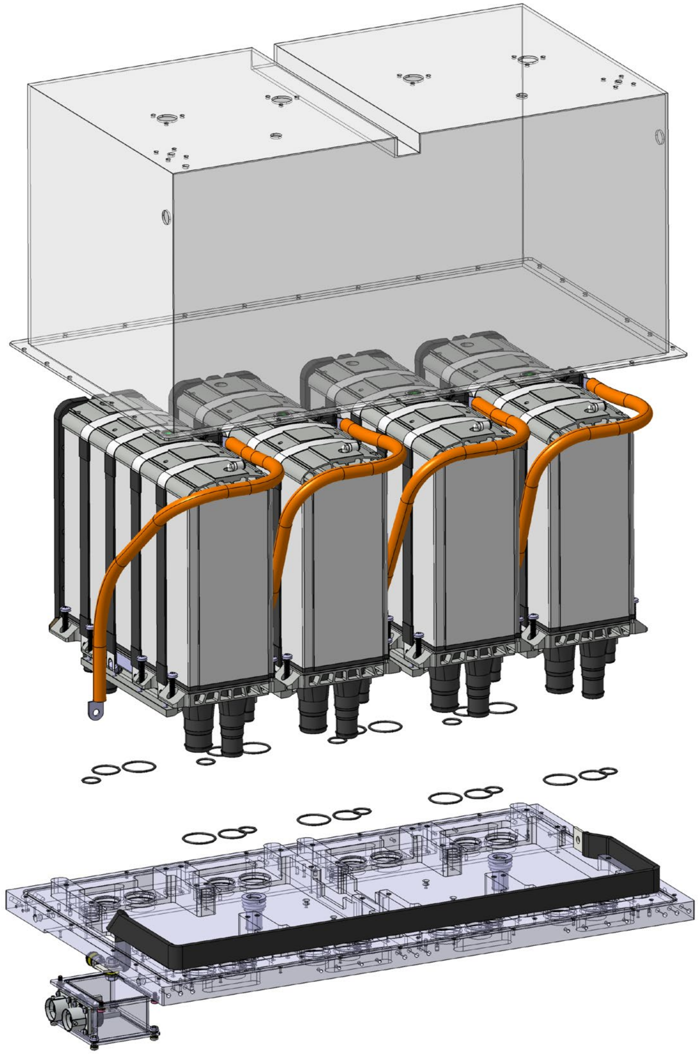
Fuel Cell Stack Modules

Parallel or serial connection

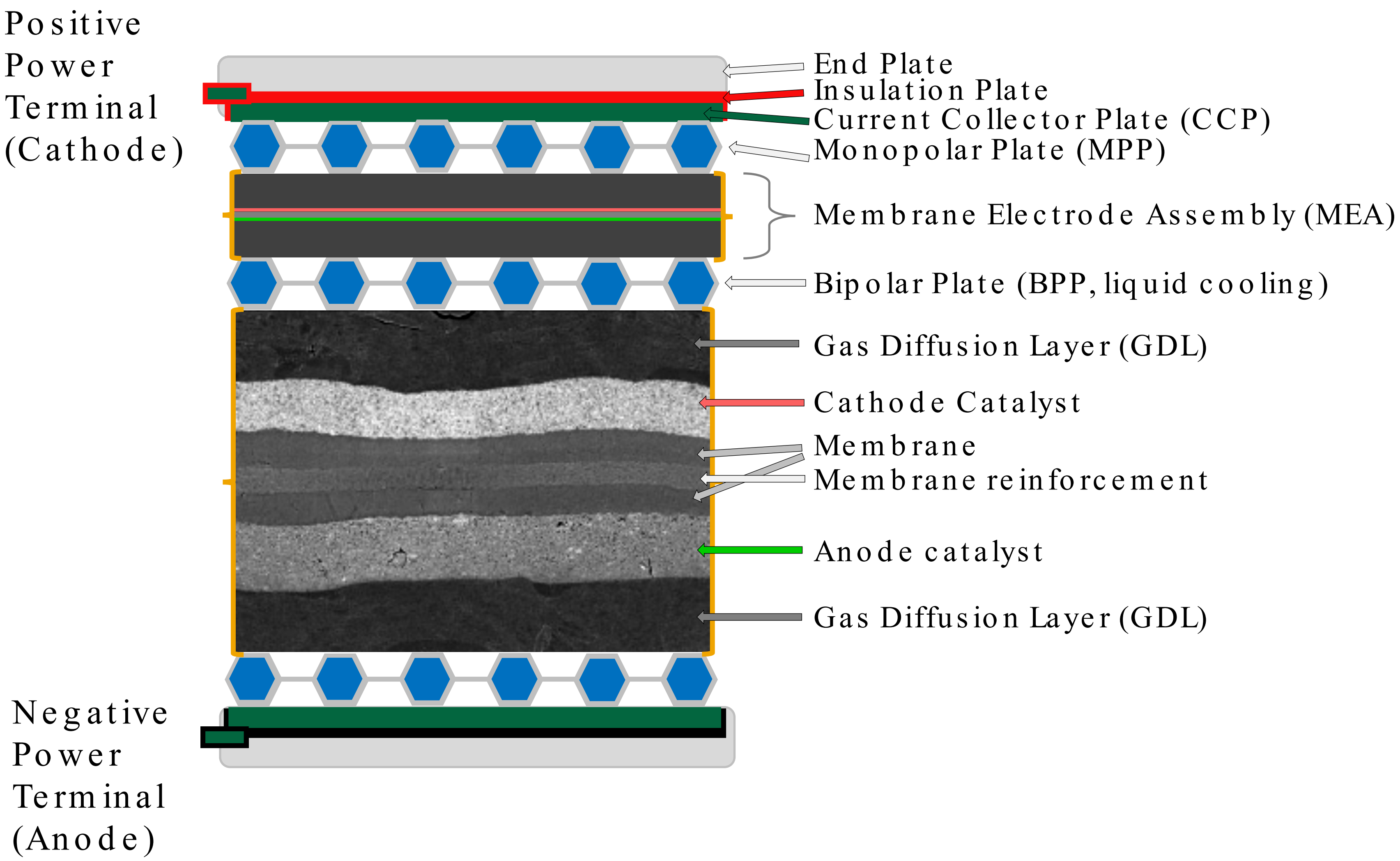
up to 1500V / ~1400 cells in series

Common media supply

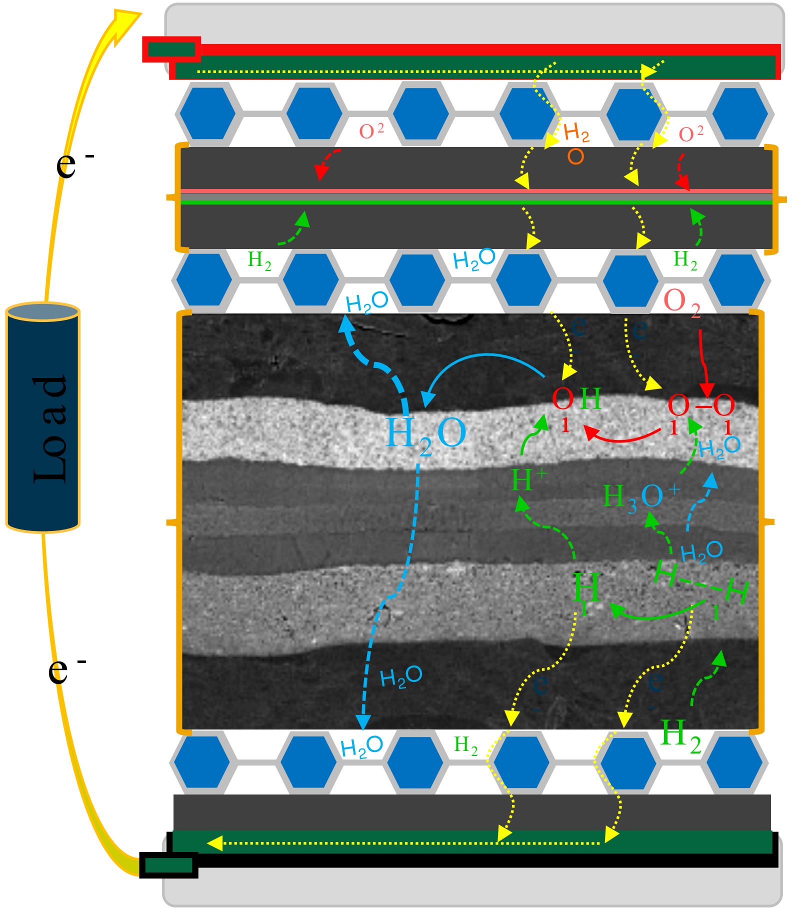




Key components of a Fuel Cell Stack



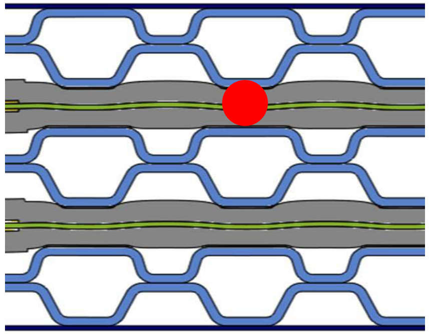
Working principle of a Fuel Cell Stack



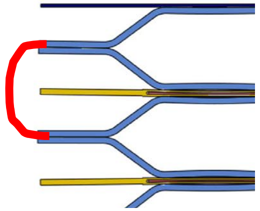
Safety risks of a fuel cell stack

FIRE

- **Internal short circuit**, caused by
  - Insufficient fuel supply
  - Insufficient cooling
  - Insufficient humidification
  - Short circuit on the external electric circuit → high current through stack
  - High voltages applied to stack



- **External short circuit**, caused by
  - Mechanical deformation of BPP ¥s
  - Particles, dust, media ingress



- **Leakage**:
  - External → H2 in ambient / enclosure
  - Anode to Cathode → H2 in exhaust
  - Anode to Coolant → H2 in coolant

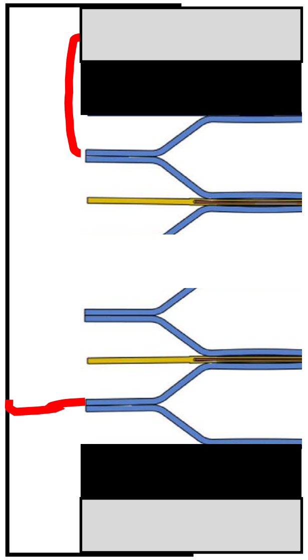
Potential explosion!

Safety risks of a fuel cell stack

Electrical hazard

➢ **Isolation fault**

- Clearance, creepage



- Coolant leakage
- Coolant contamination
- Material degradation

➢ **Direct contact**

- during service/maintainance
- during operation

Mitigation of hazardous risks

- **Design acc. to existing standards and guidelines**
  - IEC 62282-2-100 as a principal standard on fuel cell stack design and validation
  - AIR 6464
  - AS 6858
  - Isolation coordination: IEC 60664-1
  - …

- **Ventilation!**
  - Ensure sufficient ventilation around the stack and inside enclosure
  - Ensure safe release of cathode exhaust gas into open atmosphere
  - No ignition sources or hot surfaces

- **Proper system design and control**
  - Ensure operation conditions within the limits
  - Prevention of flooding and dryout
  - Cell Voltage *Monitoring* as a supporting method to detect and mitigate hazardous operation conditions

Avoidance and Detection of hazardous situation

- **Cell Voltage Monitoring (CVM)**

The CVM acts prior to safety criticality to avoid hazardous situation before they occur

- CVM can help to detect critical operation as flooding or dryout and can be used to mitigate the problem by adapting operating conditions, initiate corrective actions or reducing power output.
- Very local effects leading to hotspots can be critical to be detected early enough to avoid damage of the stack.
- External short circuits cannot be detected

- **Critical sensors to detect hazardous situations**
  - Coolant outlet temperature sensor → overheating, short circuit
  - Anode / Cathode inlet pressure sensor → leakage, undersupply
  - Power Output Monitoring (current and voltage) → undersupply, overheating
  - Isolation monitoring → electrical hazard
  - H2-sensors in the ambient → external leakage
  - H2-sensor in cathode exhaust and coolant tank → internal leakage
  - Smoke / Fire detector → fire
  - Ambient / Enclosure temperature sensor → fire

Key lessons from ~20 aviation projects

- Proper system development is crucial for both, safety, performance and durability of the fuel cell stack
- Close cooperation between system integrator and stack supplier is key
- Existing standard test procedures for validation of aviation equipment need adaptation to meet relevant fuel cell and fuel cell system safety aspects
- Further need: certification processes for
  - fuel cell stacks as single component
  - Fuel cell systems as part of an electric powertrain or as APU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Together we fly!