

Our vision is our impulsion

BATTERY EXPERTS **FORUM** 12-14.07.2022



Safety management

E-ROP electric and rotary-engined hybrid plane



Development of Propulsion Battery

Hybrid drive for Aircraft

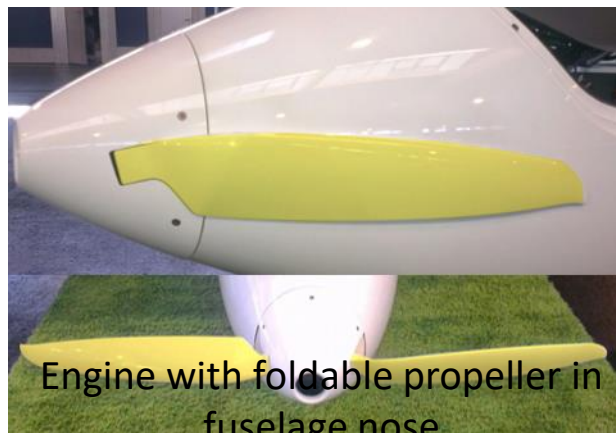
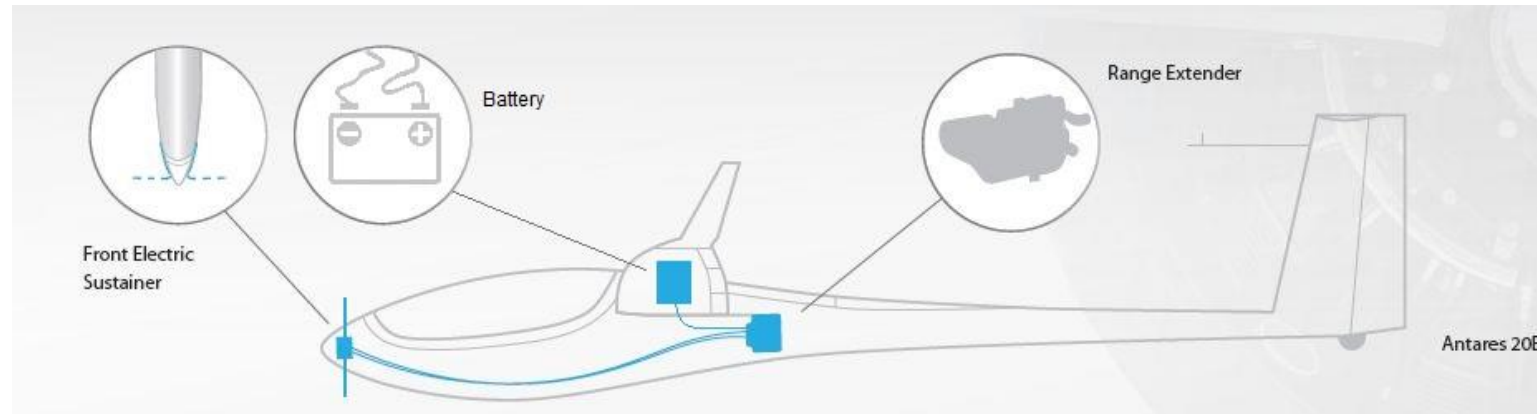
Target

- Development of an innovative drivetrain for Aircraft
- Outstanding aerodynamics, applicable for glider Aircraft
- Light-weight
- Energy supply via battery packs and electrical generator (Range Extender [REX])
- Monolever control of the drivetrain with minimized workload for the pilot



Hybrid Drive for Aircraft Concept (1)

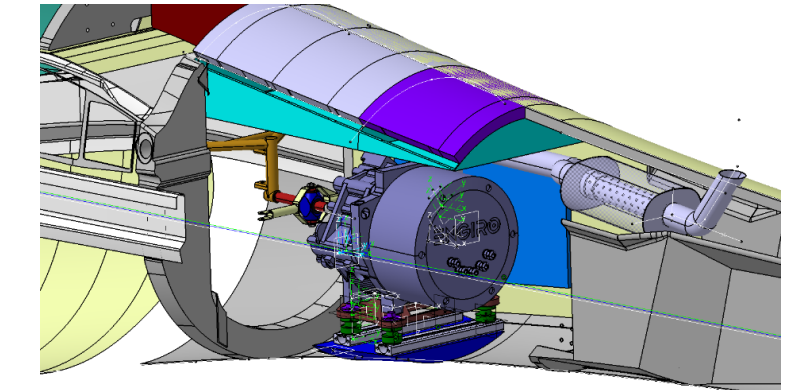
Energy generation for long range flights via combination of combustion engine (System Wankel) with Generator (Range Extender [REX])



Engine with foldable propeller in fuselage nose

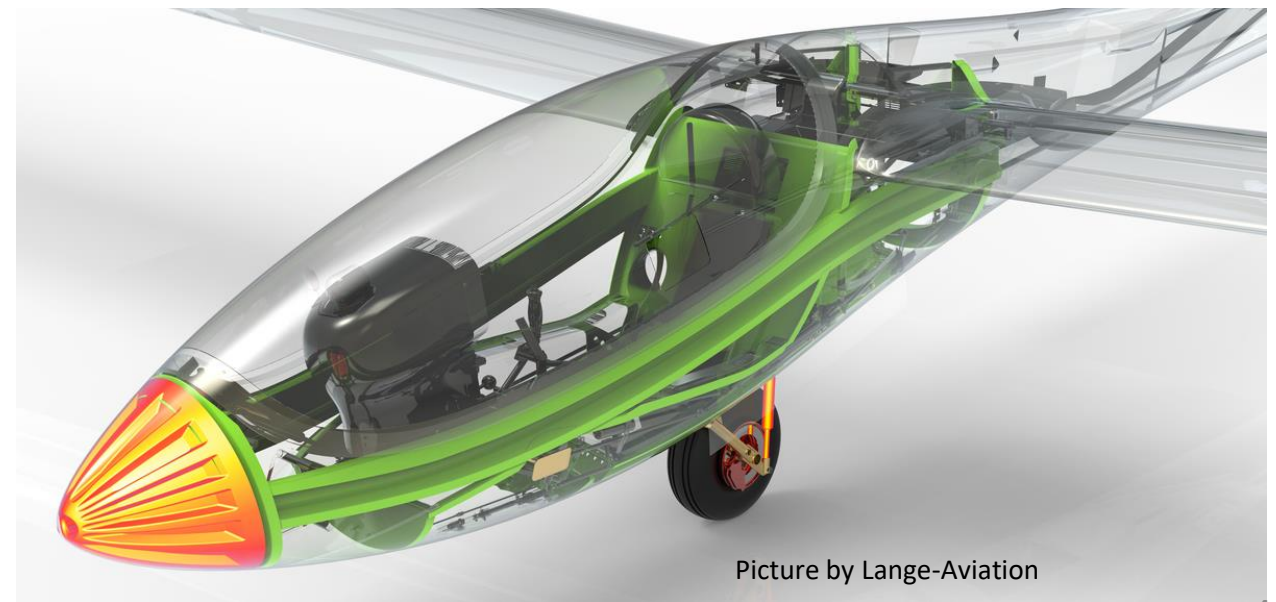


Battery Packs inside the wings © Lange Aviation



REX and tank for fossil fuel in center fuselage 3/22

- Aircraft
 - Test bed: Lange Aviation E1 Antares
 - Excellent qualities as a glider
 - High fuselage and high landing gear enabling a large diameter propeller (1,2 Meter) at the nose
 - Spacious engine compartment providing room for REX und fuel tanks (35l)
 - Existing battery compartments in the wings
 - Internal fuselage structure is very suitable to adaptation of a front propeller drive



Picture by Lange-Aviation

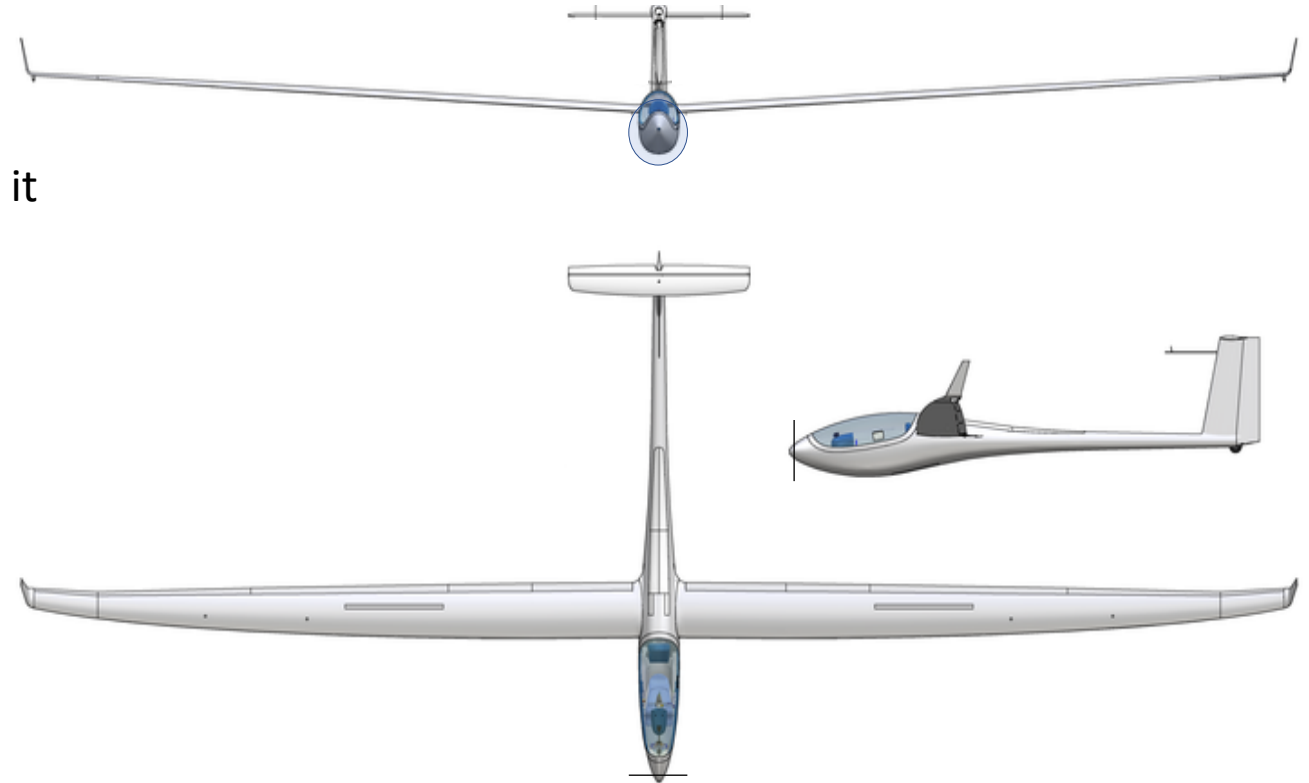
Hybrid Drive for Aircraft

Technology (2)

- Aircraft

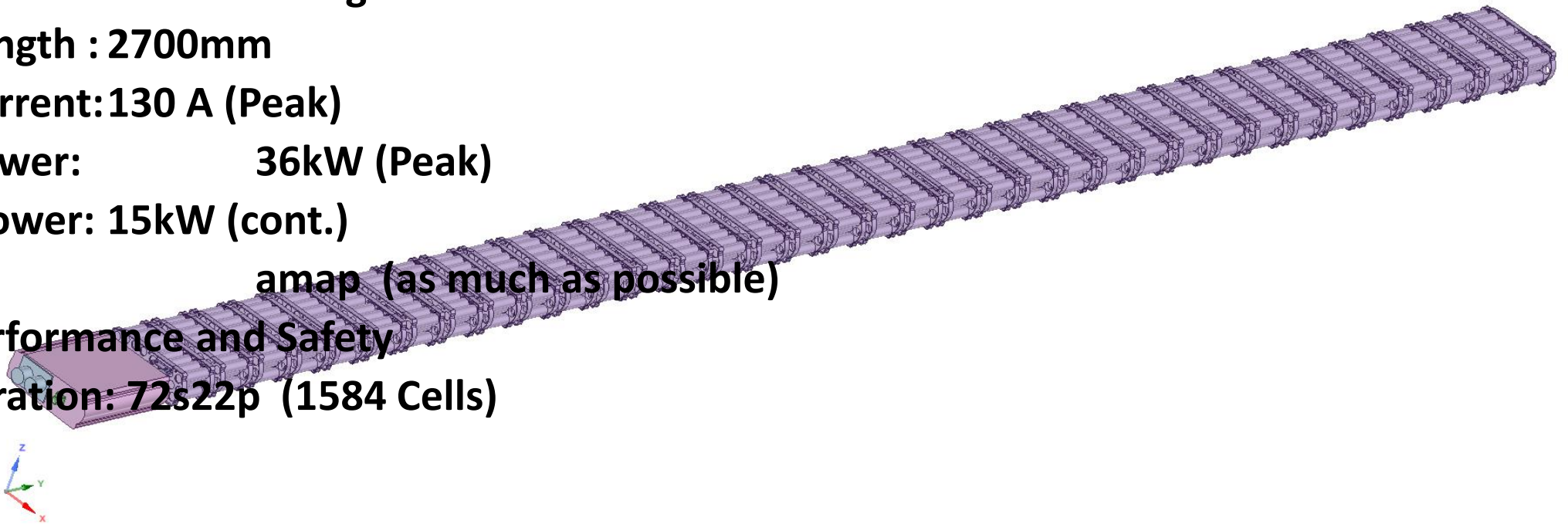
- Calculated Performances

- Maximum glide ratio: 54 (from 1000m altitude it can glide a distance of 54km)
- Maximum takeoff weight (MTOW): 660 kg
- Water ballast capacity: 210-350 L
- Battery Capacity : 17,4 kWh
- Max. Range in powered flight: 2500km
- Max. Endurance 14 hours



Specification of new Battery

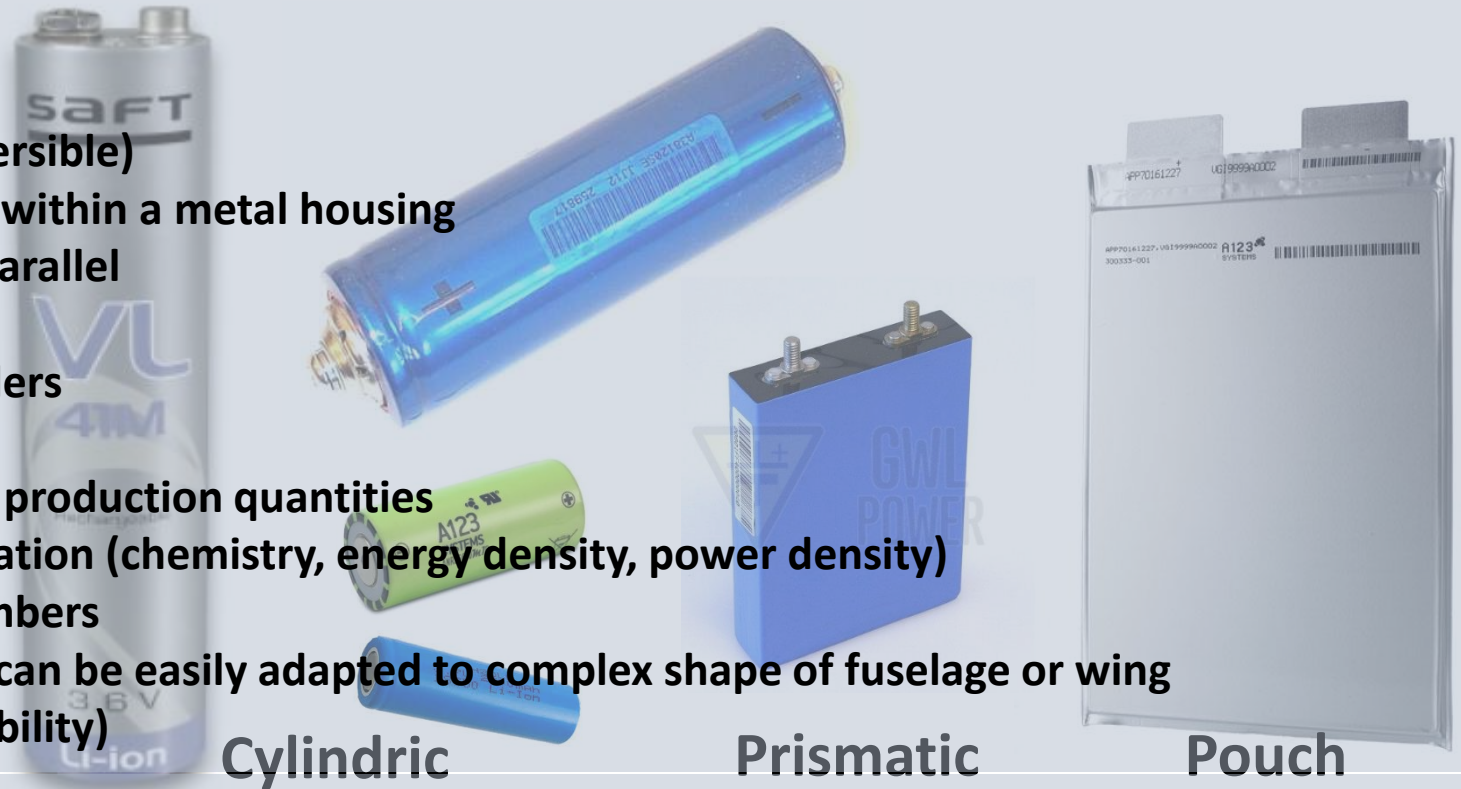
- Voltage: 216V – 288V
- Weight: ~77kg
- max. Length : 2700mm
- max. Current: 130 A (Peak)
- max. Power: 36kW (Peak)
- cont. Power: 15kW (cont.)
- Energy: amap (as much as possible)
- High Performance and Safety
- Configuration: 72s22p (1584 Cells)



Which Type of Cell

Advantages of 18650 Cells

- **Safety**
 - Every cell has an integrated fuse (irreversible)
 - Single cell has small amount of energy within a metal housing
 - Redundancy: mostly a lot of cells are parallel
- **Availability**
 - Many different manufacturers / providers
 - High volume product
 - Low cost, due to competition and high production quantities
- **Wide selection spectrum facilitates optimization (chemistry, energy density, power density)**
- **Reproducibility, due to high production numbers**
- **Form Factor: Cells of small cylindrical shape can be easily adapted to complex shape of fuselage or wing**
- **Dimensions are standardized (interchangeability)**



Cylindric Cells

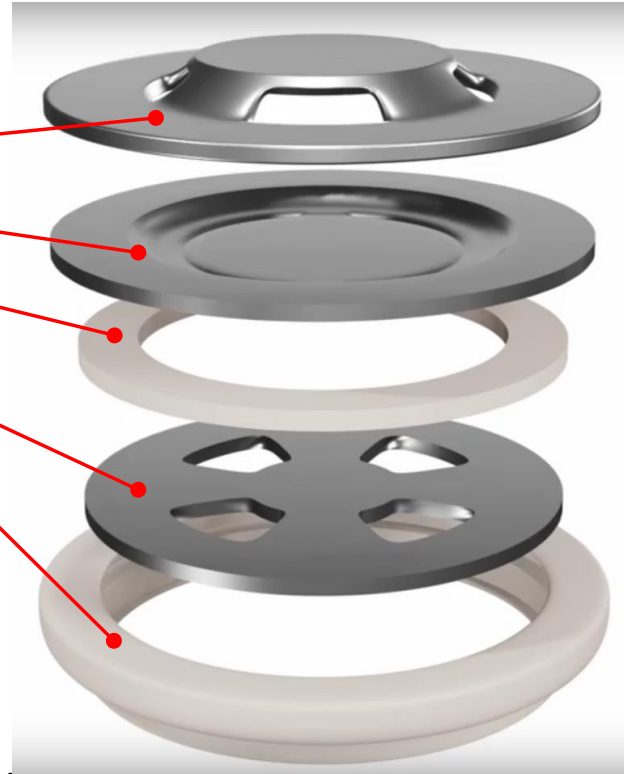
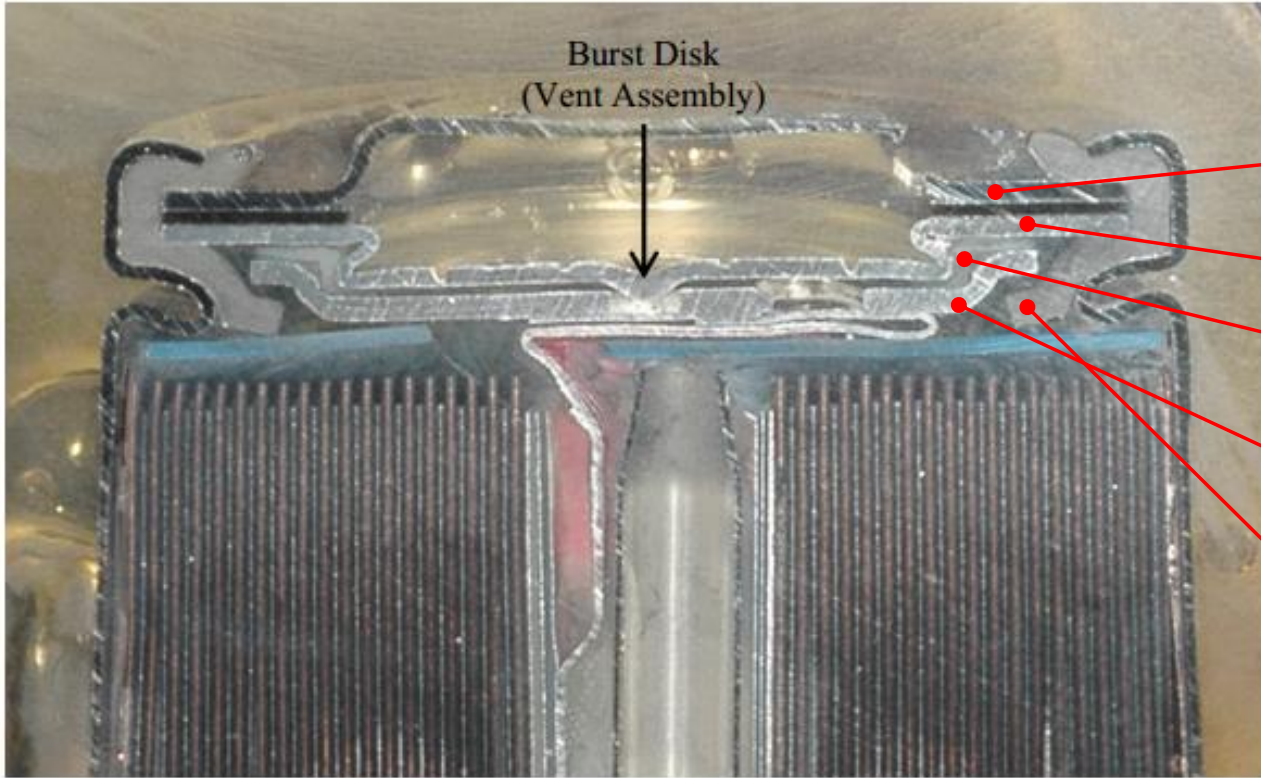
Prismatic Cells

Pouch Cells

Disadvantages of 18650 cells

- Many cells (> 1500pcs) must be connected electrically and mechanically

CID (Current Interrupt Device) in Cylindrical 18650/21700 cells



- Positive Terminal
- Burst disc
- Insulator ring
- Current collector disc
- Sealing ring

Cap assembly cross section of an 18650 cell with burst disk indicated

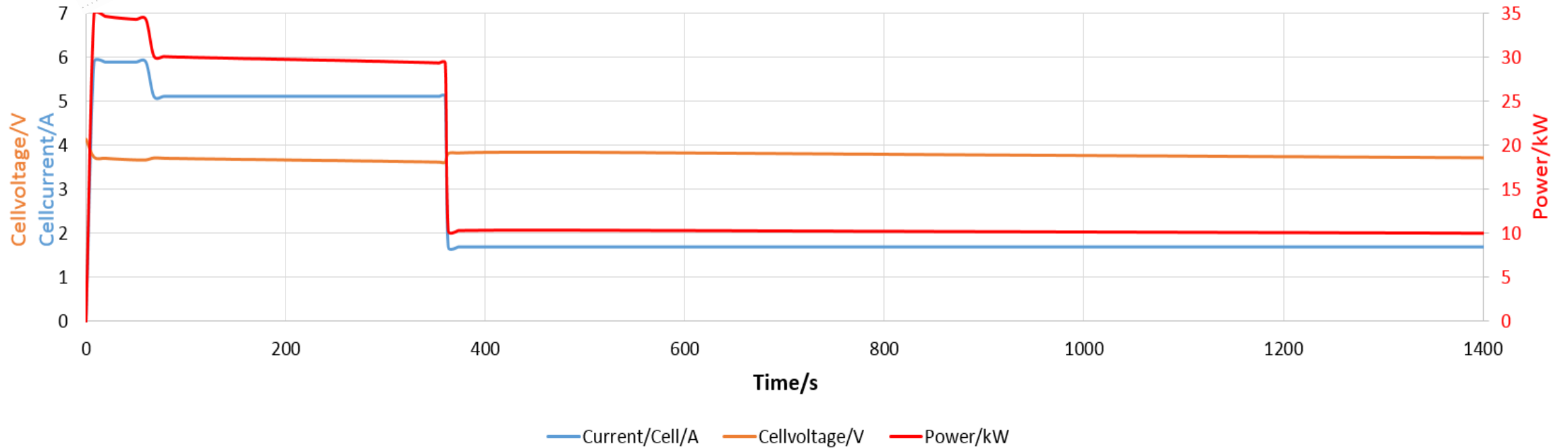
(Lithium-Ion Batteries Hazard and Use Assessment, July 2011 Fire Protection Research Foundation))

Evaluation of different 18650/21700 Cells – Power Profile

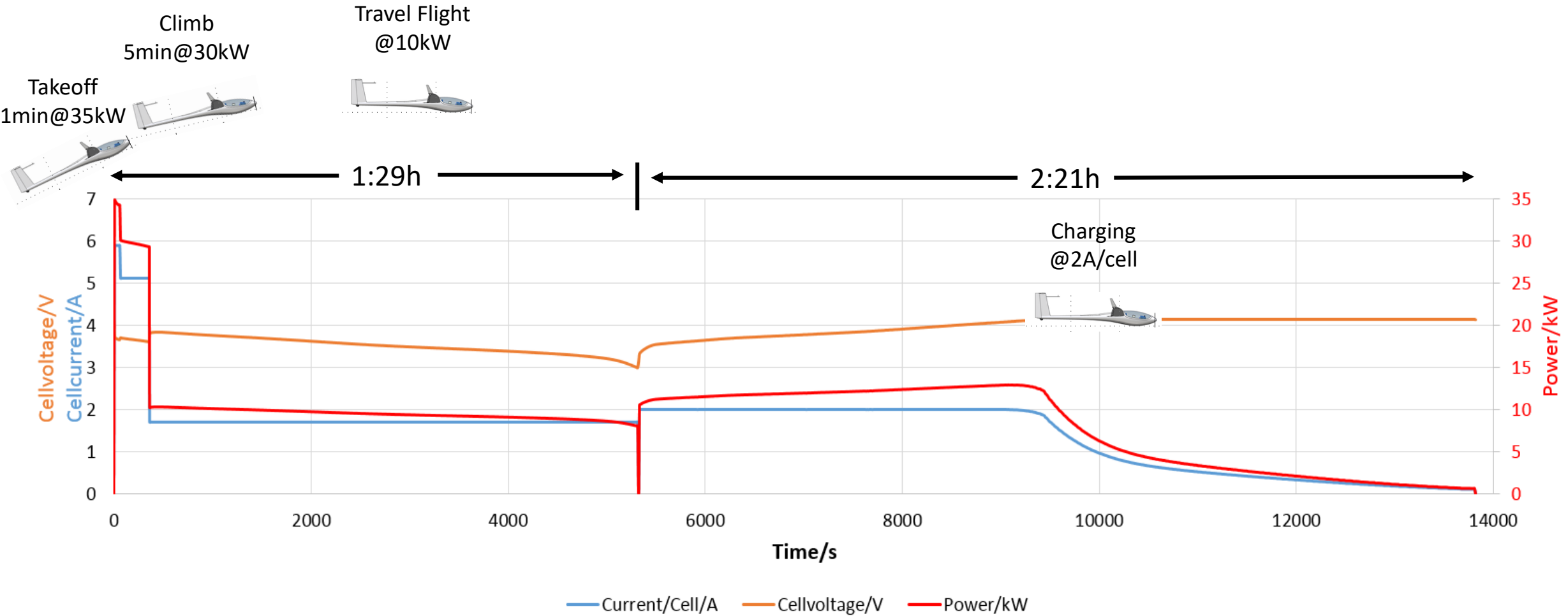
Takeoff
1min@35kW

Climb
5min@30kW

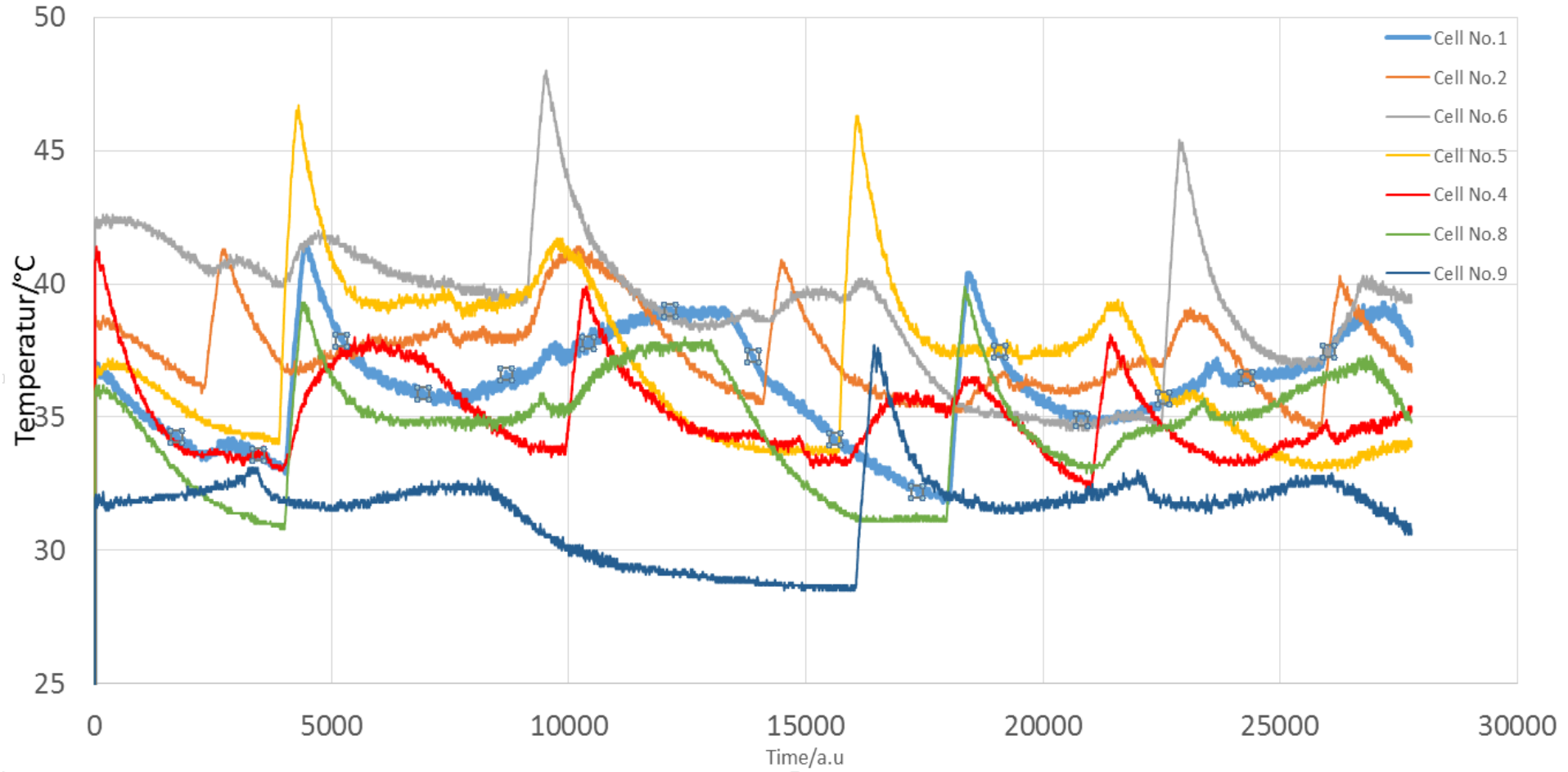
Travel Flight
@10kW



Evaluation of different 18650/21700 Cells – Power Profile

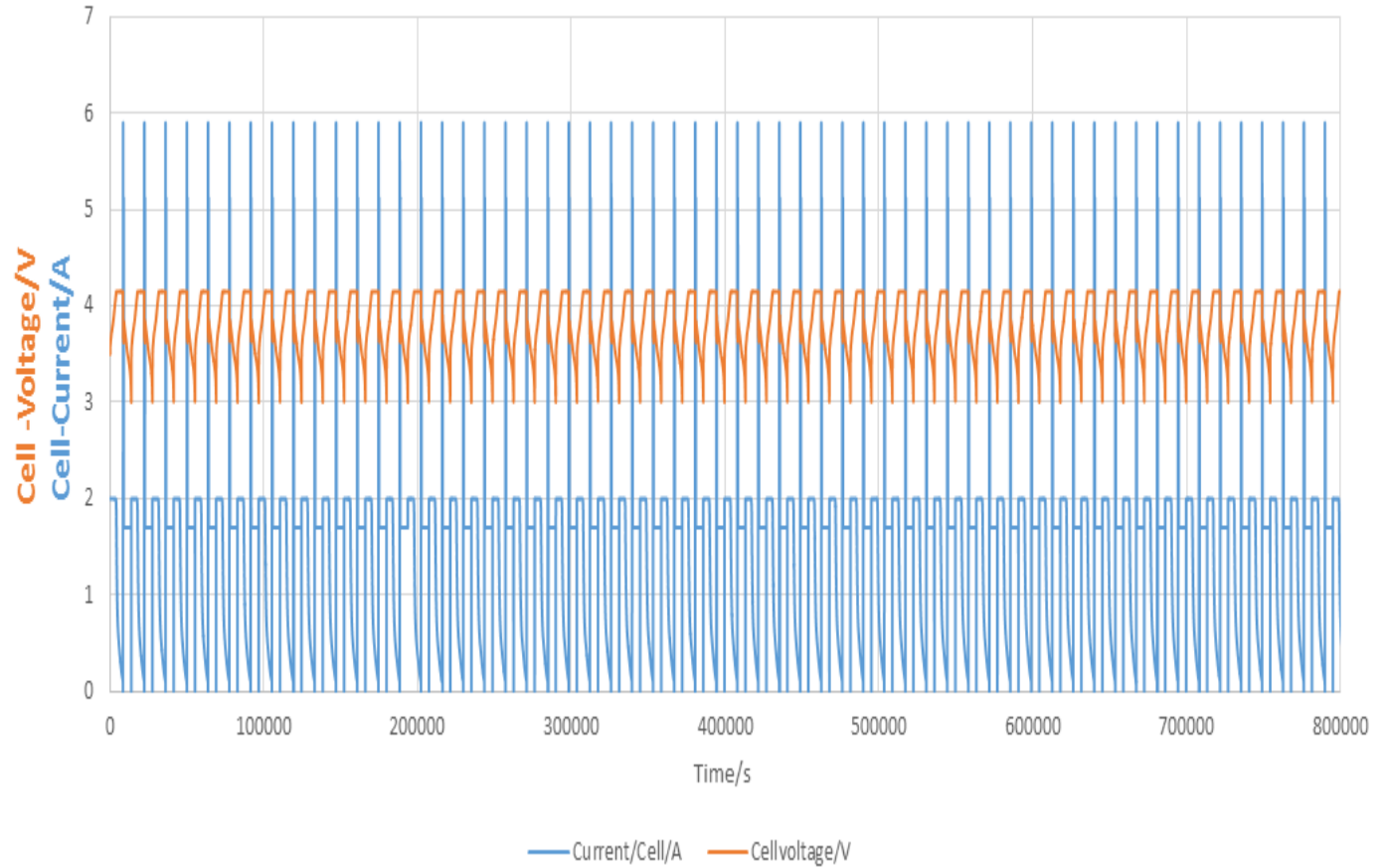
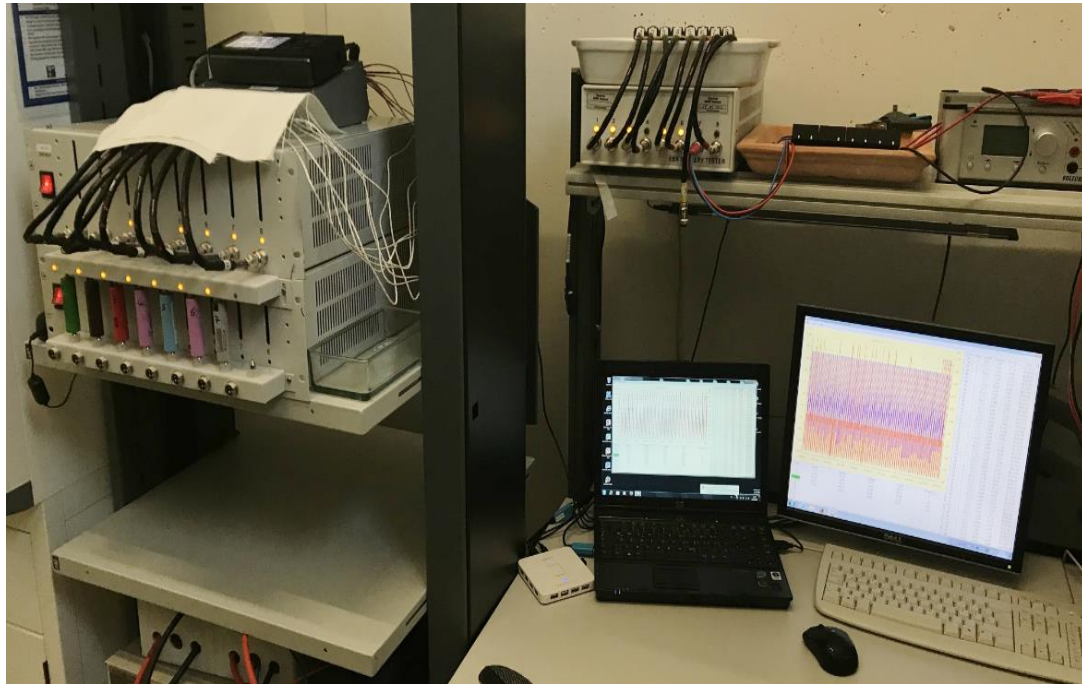


Temperature of different Cells during Cyclisation



Lifetime Evaluation of different 18650/21700 Cells

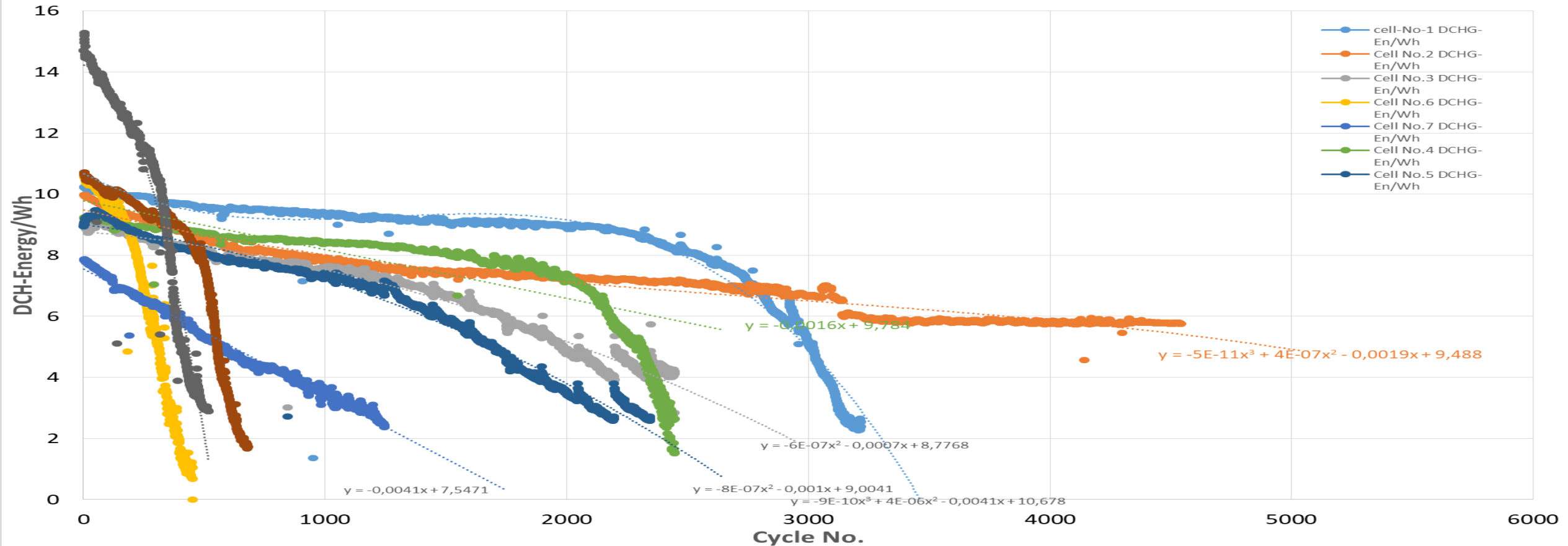
Cycling for Lifetime Evaluation



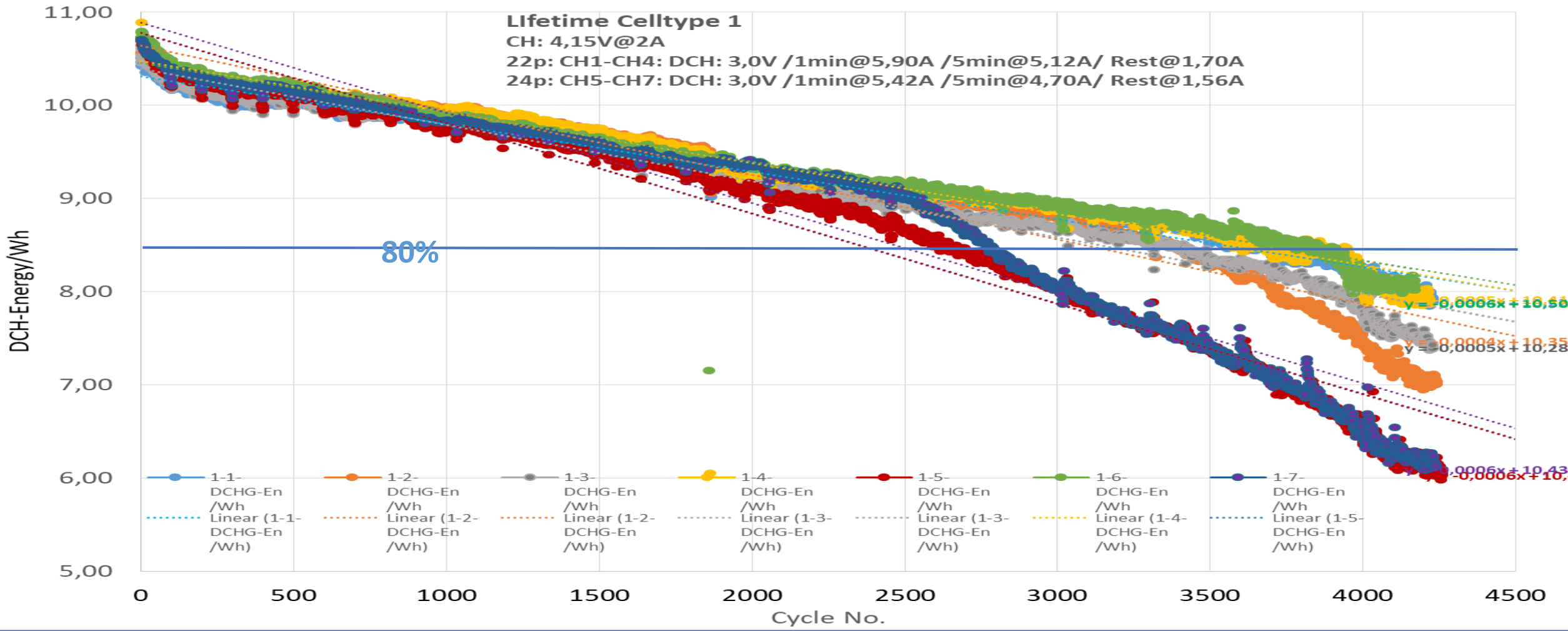
Lifetime Evaluation of Suitable 18650/21700 Cells

Lifetime

18650 (24p) Cycle: CH: 2A/4,2V DCH: 1min@5,42A / 5min@4,7A / until 3V@1,56A
 21700 (18p) Cycle: CH: 2A/4,2V DCH: 1min@7,2A/5min@6,3A/until 3V@2,1A



Lifetime/Comparative Evaluation of Cell No.1

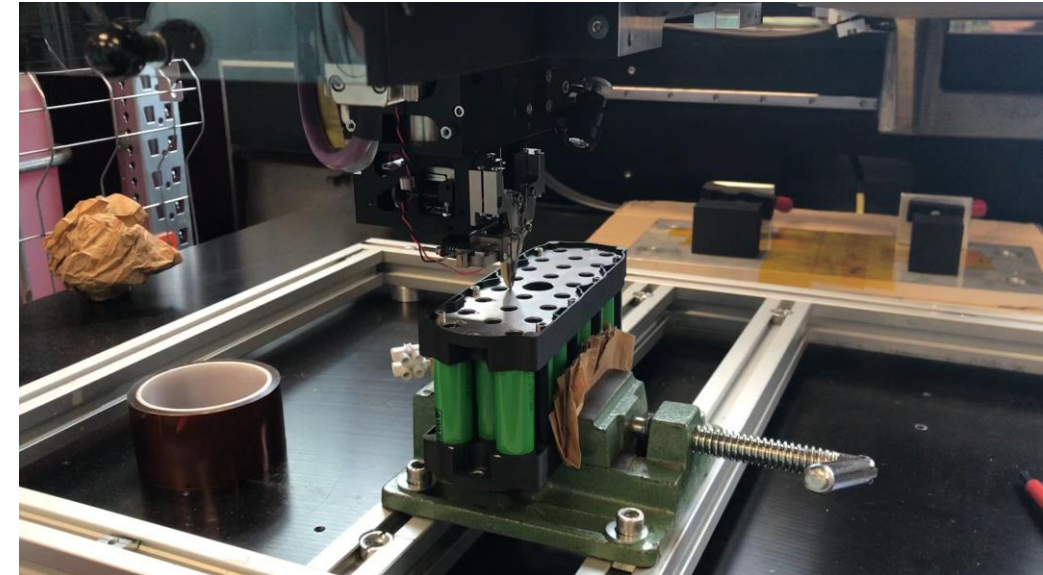
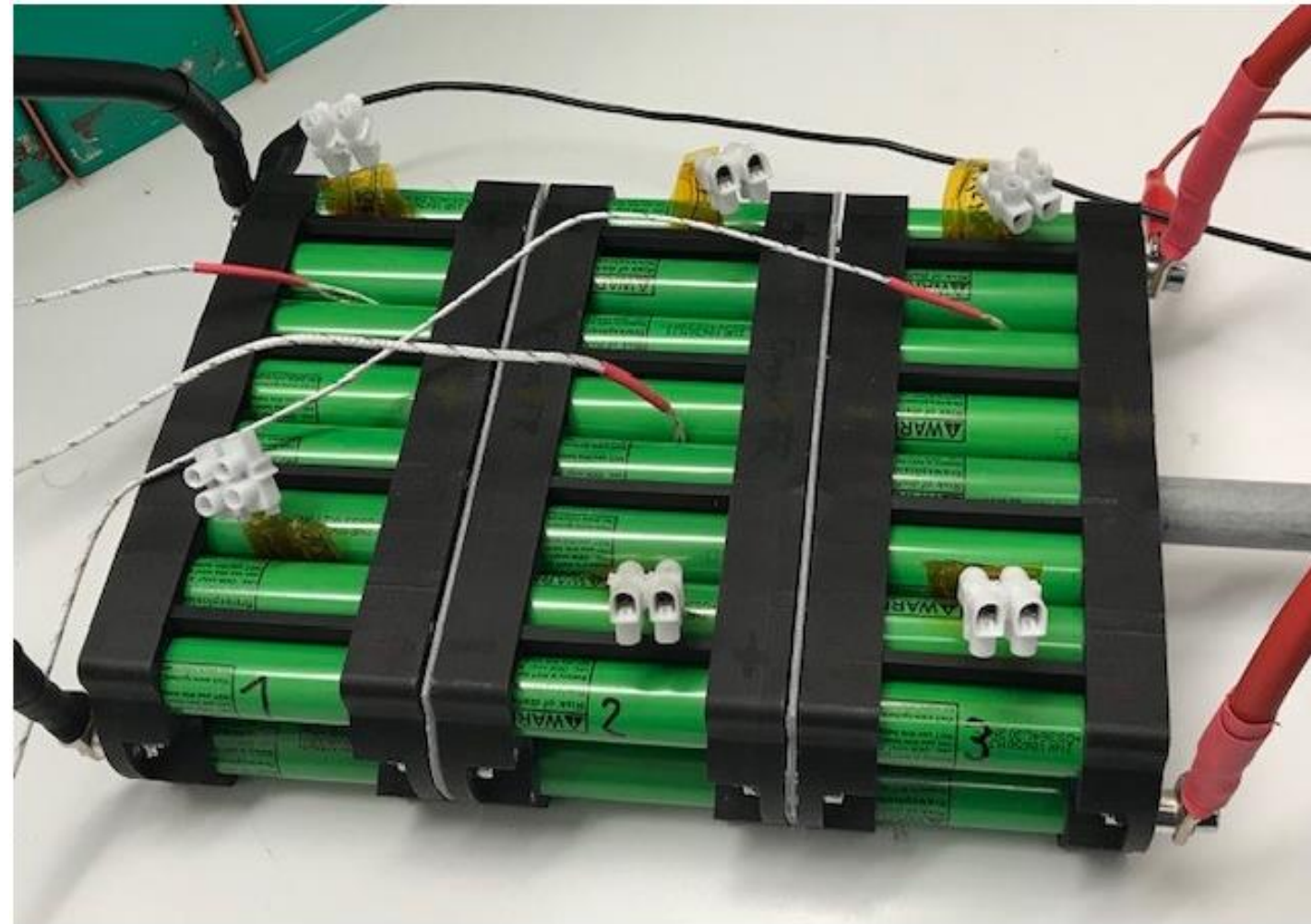


Preparation Battery Block 3s22p for Tests



Preparation of single 18650 cell with heater coil to drive into termal runaway

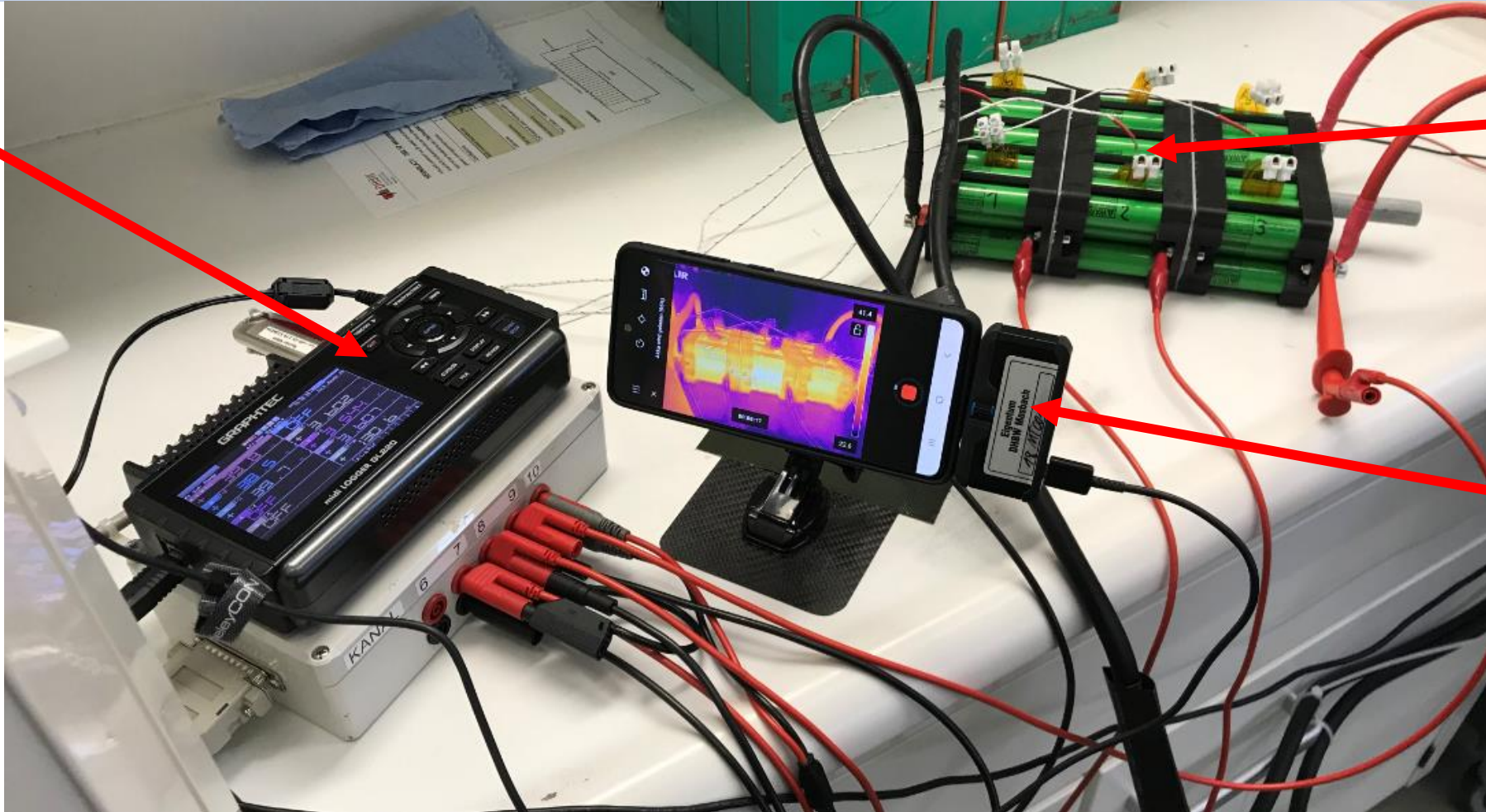
Preparation Battery Block 3s22p for Tests



Video: Bonding of 18650 cells

Performance Test of 3s22p Battery Block @ 130A

Datalogger:
Temperatures
Cell Voltages



3s22p
Battery-Block
With
Thermocouples

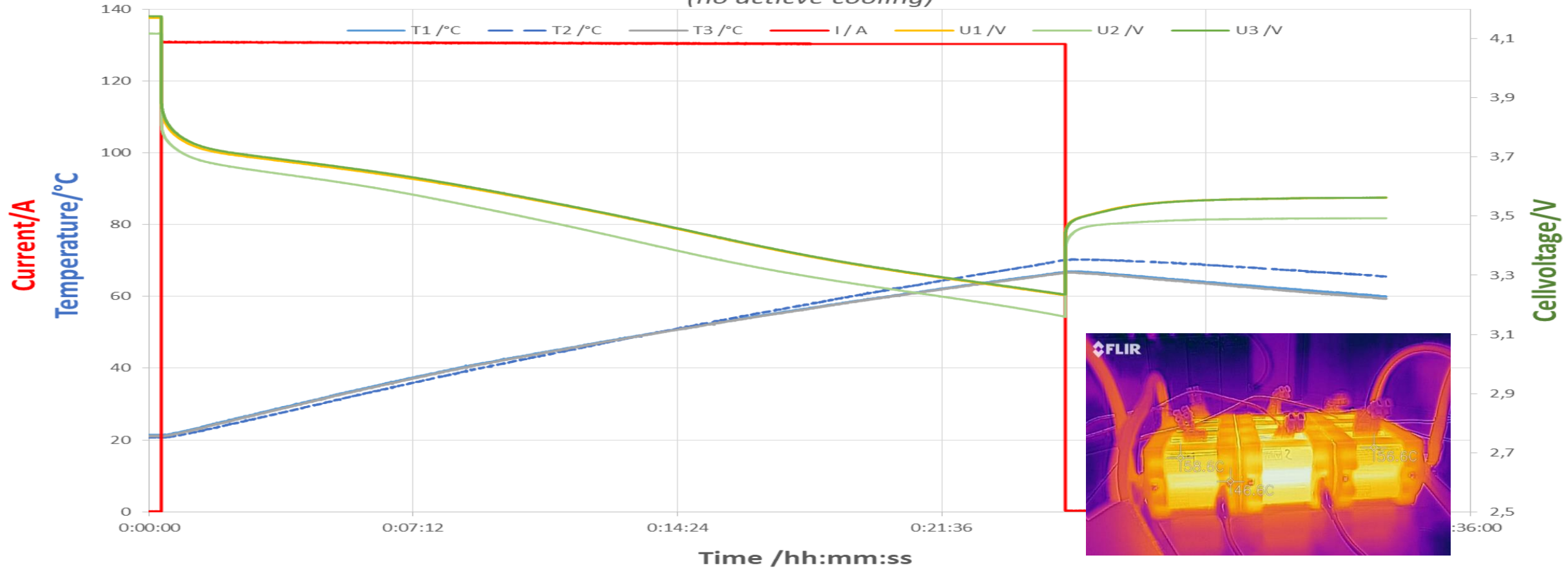
IR-Camera

Performance Test of 3s22p Battery Block @ 130A

Discharge 3s22p @ 130A

2021-03-13

(no active cooling)

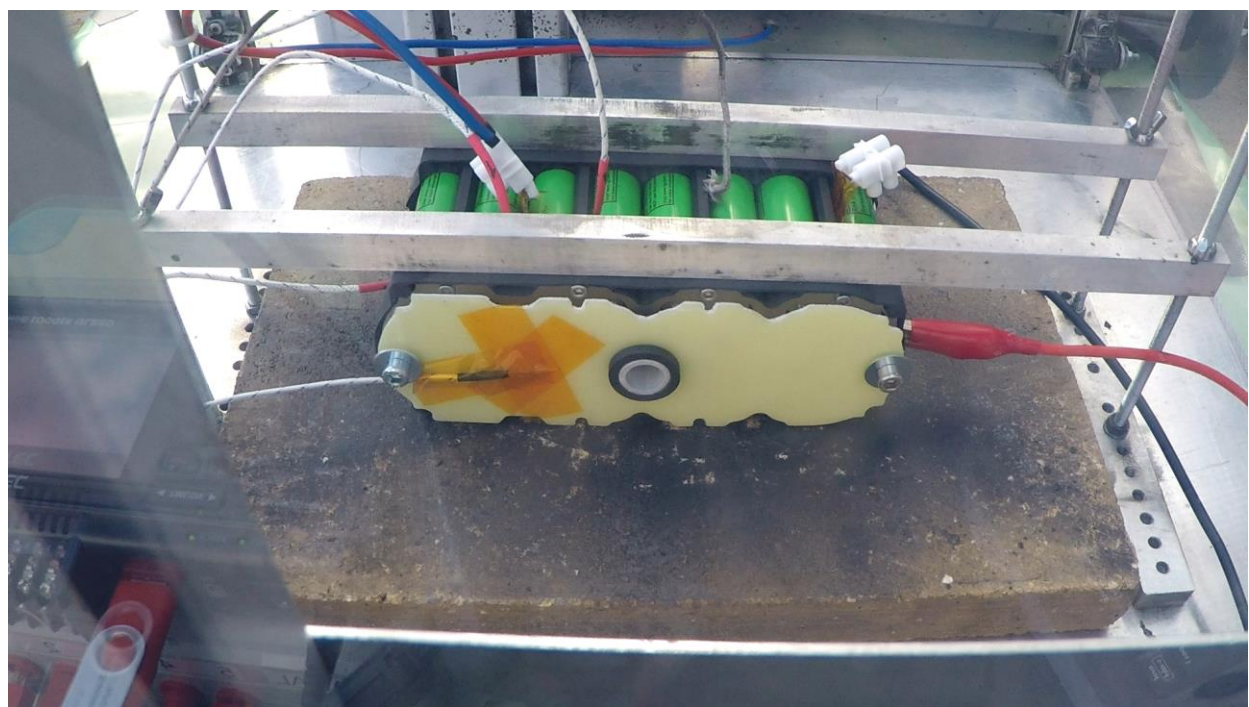


Test: Induced Thermal Runaway of a single 18650 cell within a 22p Block

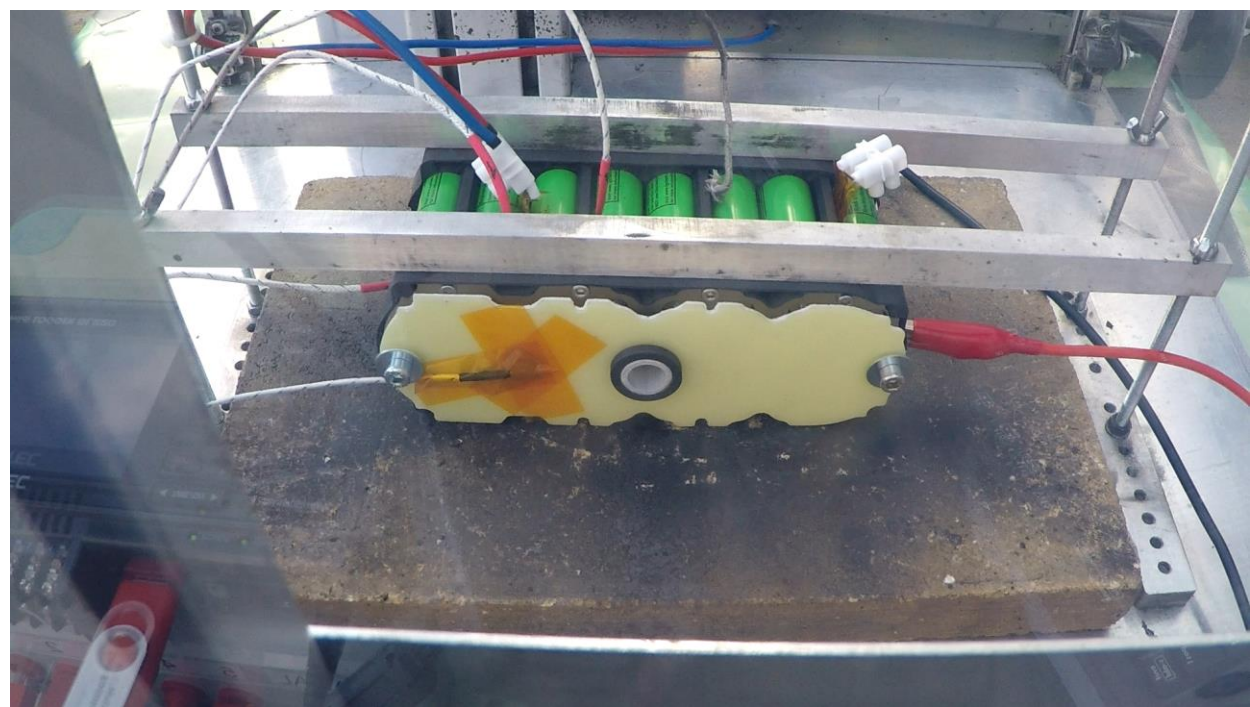


Single 18650 cell with heater coil to drive into thermal runaway

Test: Induced Thermal Runaway of a single 18650 cell within a 22p Block



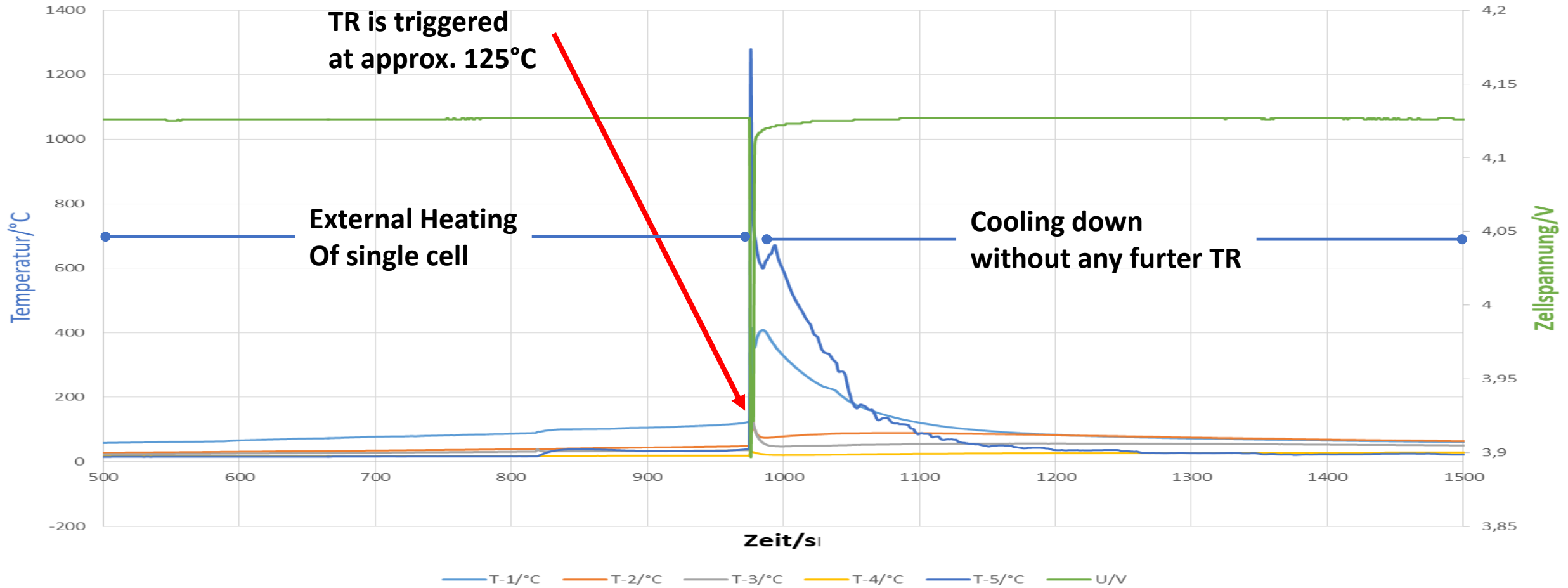
Video-1: Overpressure fuse opens and should disconnect cell



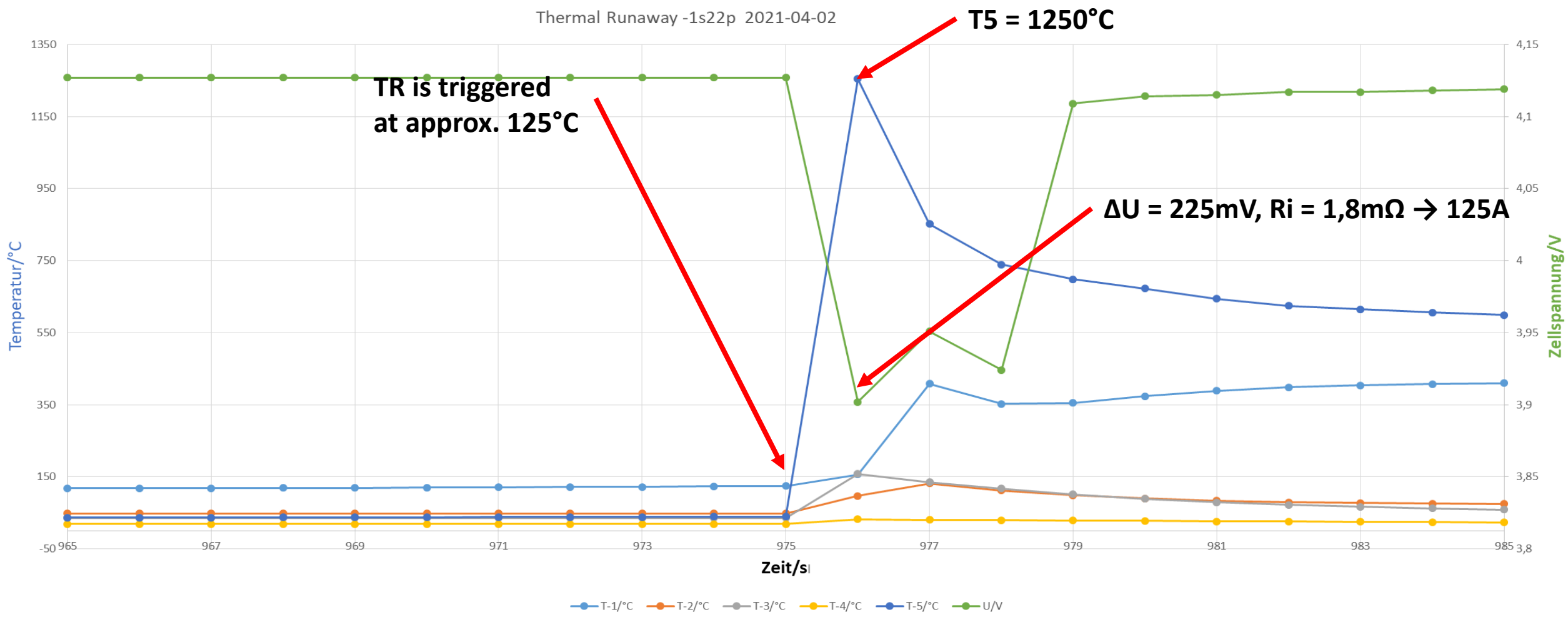
Video-2: A few minutes later thermal runaway of single cell
But no chain reaction of other cells !!

Test: Induced Thermal Runaway of a single 18650 cell within a 22p Block

Thermal Runaway -1s22p 2021-04-02



Test: Induced Thermal Runaway of a single 18650 cell within a 22p Block

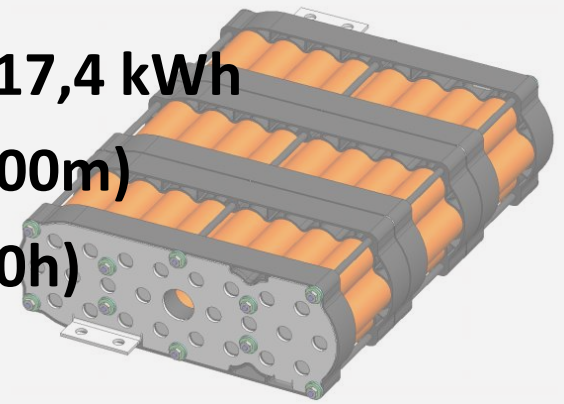
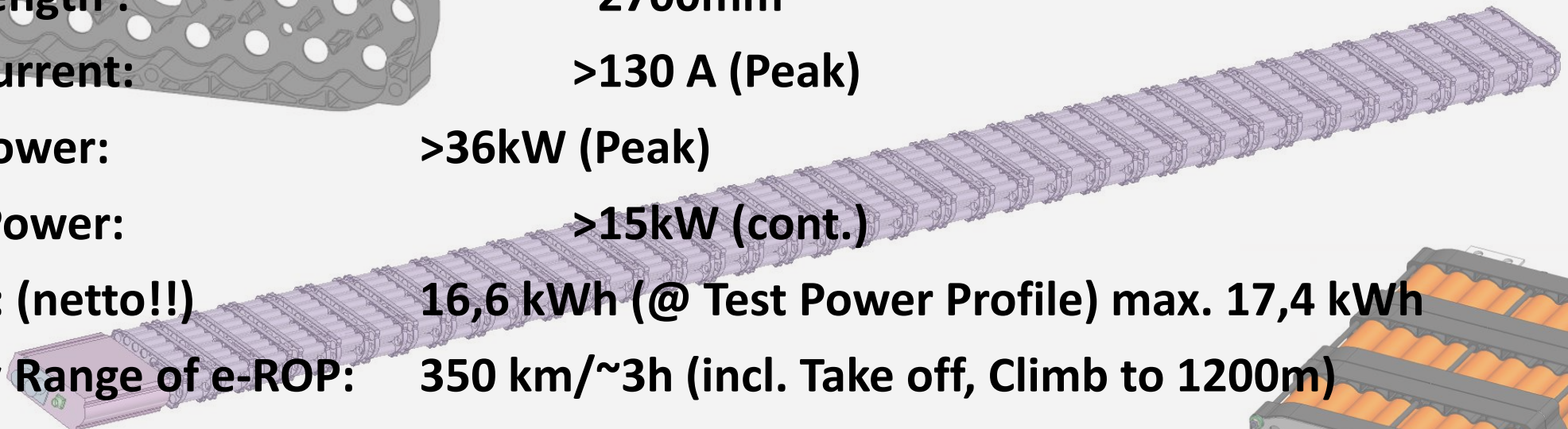
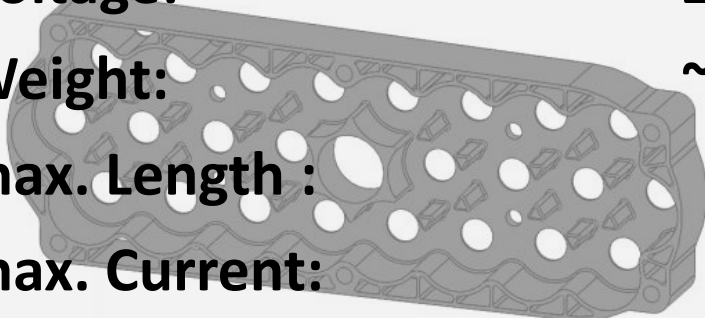


Test: Induced Thermal Runaway of a single 18650 cell within a 22p Block



Battery Performance

- Voltage: 216V – 299V (3V – 4,15V/cell)
- Weight: ~80kg
- max. Length : ~2700mm
- max. Current: >130 A (Peak)
- max. Power: >36kW (Peak)
- cont. Power: >15kW (cont.)
- Energy: (netto!!) 16,6 kWh (@ Test Power Profile) max. 17,4 kWh
- Battery Range of e-ROP: 350 km/~3h (incl. Take off, Climb to 1200m)
- Battery Lifetime > 3000 Cycles (80%) (>1 *10⁶ km / 9000h)



Hybrid Drive for Aircraft Status Aircraft



First full assembly of aircraft



Structural certification tests for motor mounting and battery/REX mounting at DLR Stuttgart



Thank you for your Attention



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