Saft VL10ES Space Cell and Battery Qualification Status

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Summary

1. Objectives and markets
2. Cell Development
3. Battery Designs
4. Conclusions

Objectives and markets

VL10ES NEXT GENERATION CELL AND BATTERY

TECHNICAL PERFORMANCE

- Over 220 Wh/Kg to reduce battery weight
- High DOD cycling ranges: LEO 30% and GEO 70%
- Innovation on densification of electrodes
- Specific materials to preserve long life

SAFETY ENSURED

- Compatible with safety launch pad
- Robust stainless steel casing

PRICE REDUCTION

- Reduce the battery price
- Address LEO, GEO, MEO, constellation markets
- Less cells in large batteries

GEO/MEO satellites
Low to high power
5 to 30 kW

Standard LEO &
Constellation LEO satellites
With long lifetime

VL10ES Performances objectives

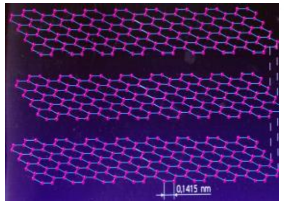
CELL TYPE	VL10ES (F-size)
Voltage Range	2.7 V - 4.2 V
Nominal Capacity	> 12 Ah @ 4.2V, 20°C
Nominal Energy	> 46 Wh @ 4.2V, 20°C
Specific Energy	>= 220 Wh/kg
Internal Resistance	≤22 mΩ @ 20% DoD / TBC
Operating Temperature	+10°C / +40°C
Mechanical Design Margins	EWR & ECSS compliant

Cell Development

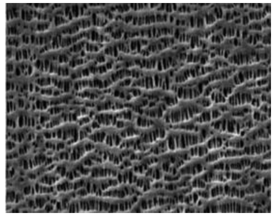
Cell concept for high specific energy, long life and safety

Electrolyte
Formulation optimization for LEO

Negative electrode
Innovating graphite blend for high DOD and long-life LEO



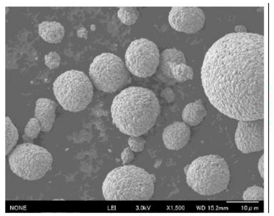
Specific separator
Electrolyte reservoir for long range cycling



Circuit breaker
Similar to VES16

Symmetric double vent safety device
for thermal runaway management

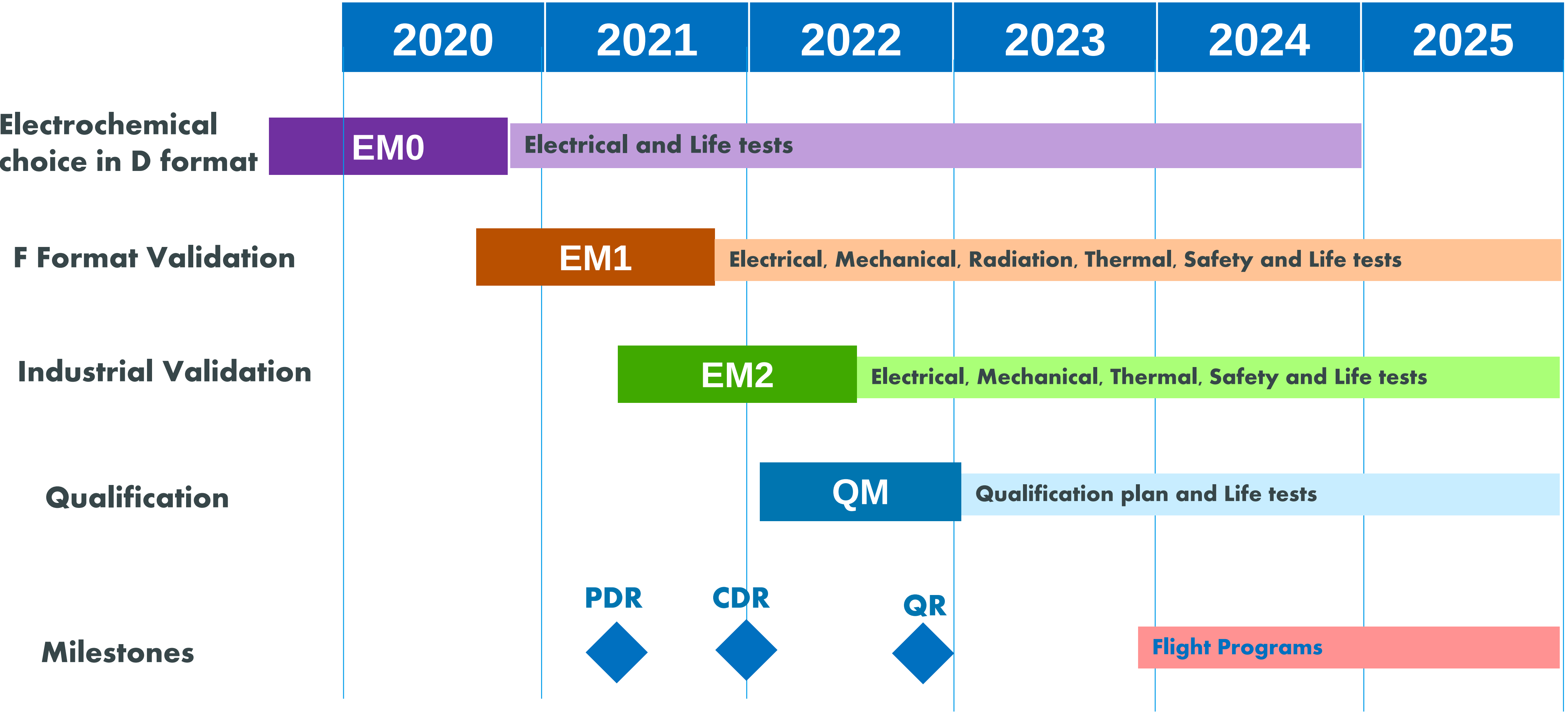
Positive electrode
Innovating densification to increase specific energy with NCA materials



Thick Stainless-steel casing
Welded cover

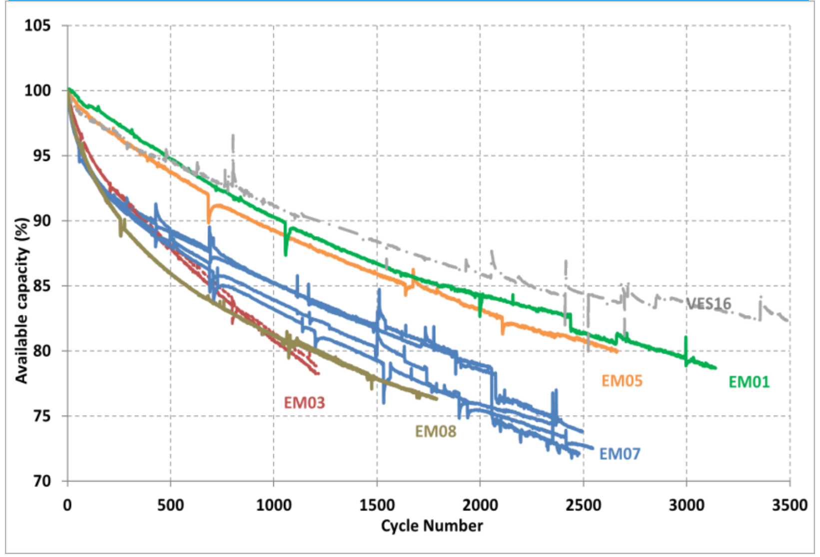
TotalEnergies

Development Plan

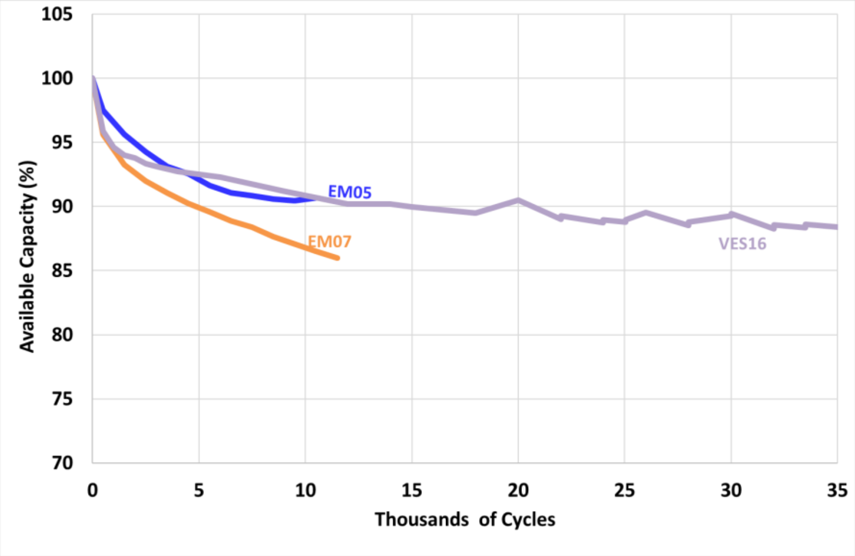


Electrochemistry development: EM0 (D-format) cycling results

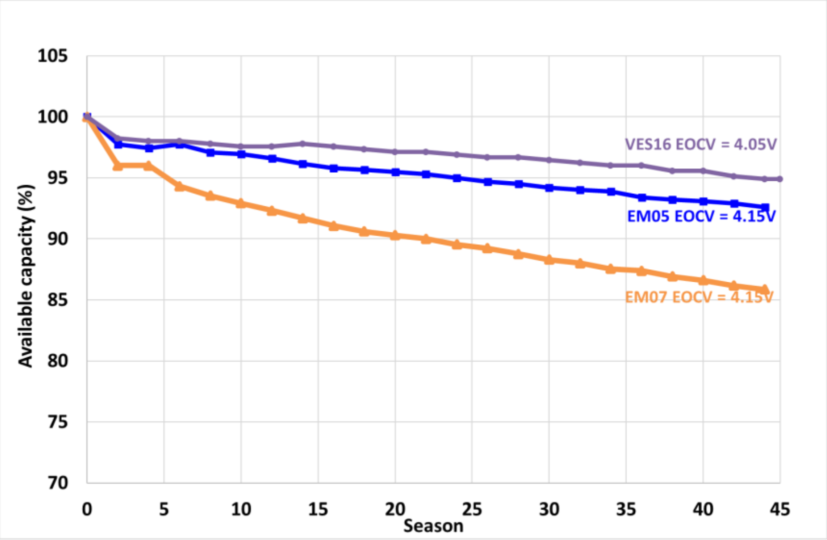
Accelerated 100% DOD cycling C/3-D/2



LEO cycling at 30% DOD



Accelerated GEO cycling at 70% DOD

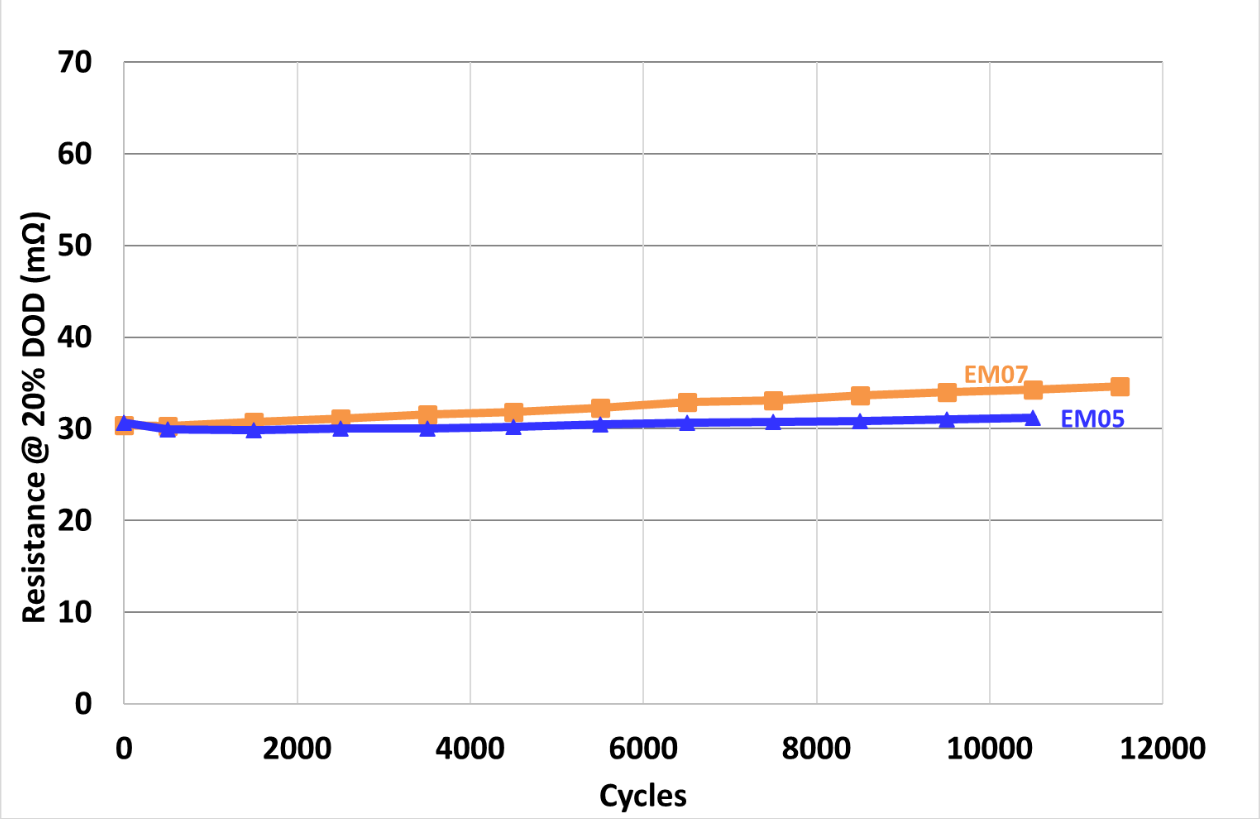


14 electrochemitry combinations tested / 2 families selected for EM1

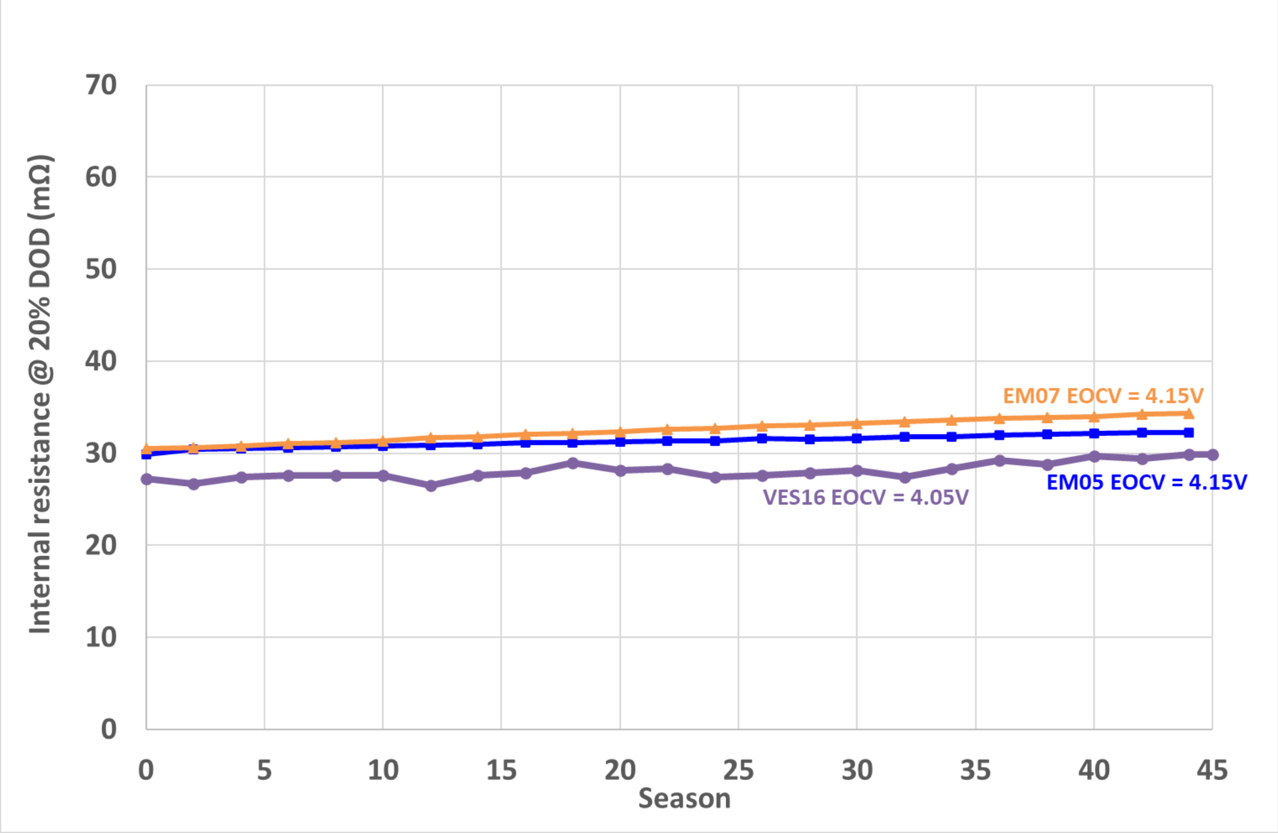
- LEO cycling: Energy loss of EM0 are showing similar trends as VES16 in LEO 30% after 11500 cycles and answer to 12 years missions
- GEO cycling: EM0 chemistry demonstrated 45 GEO seasons (equivalent to 22.5 years) with limited fading

EM0 (D-format) internal resistance results

Internal resistance @20% DOD, 30% real time LEO cycling



Internal resistance @20% DOD, GEO 70% DOD cycling



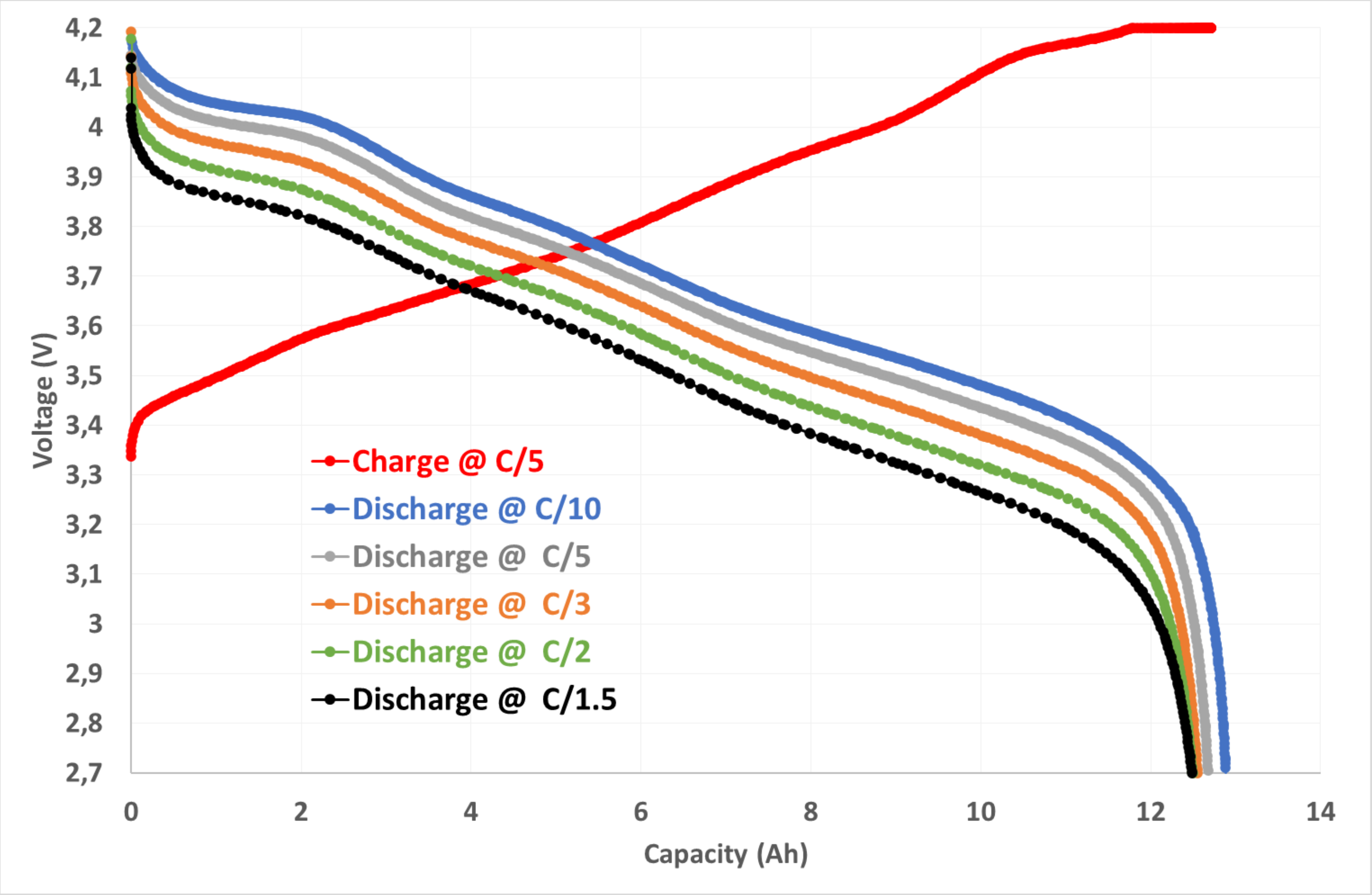
Stable internal resistance, answering to both LEO and GEO missions

TotalEnergies

EM1 Cell Results

VL10ES EM1 performances :

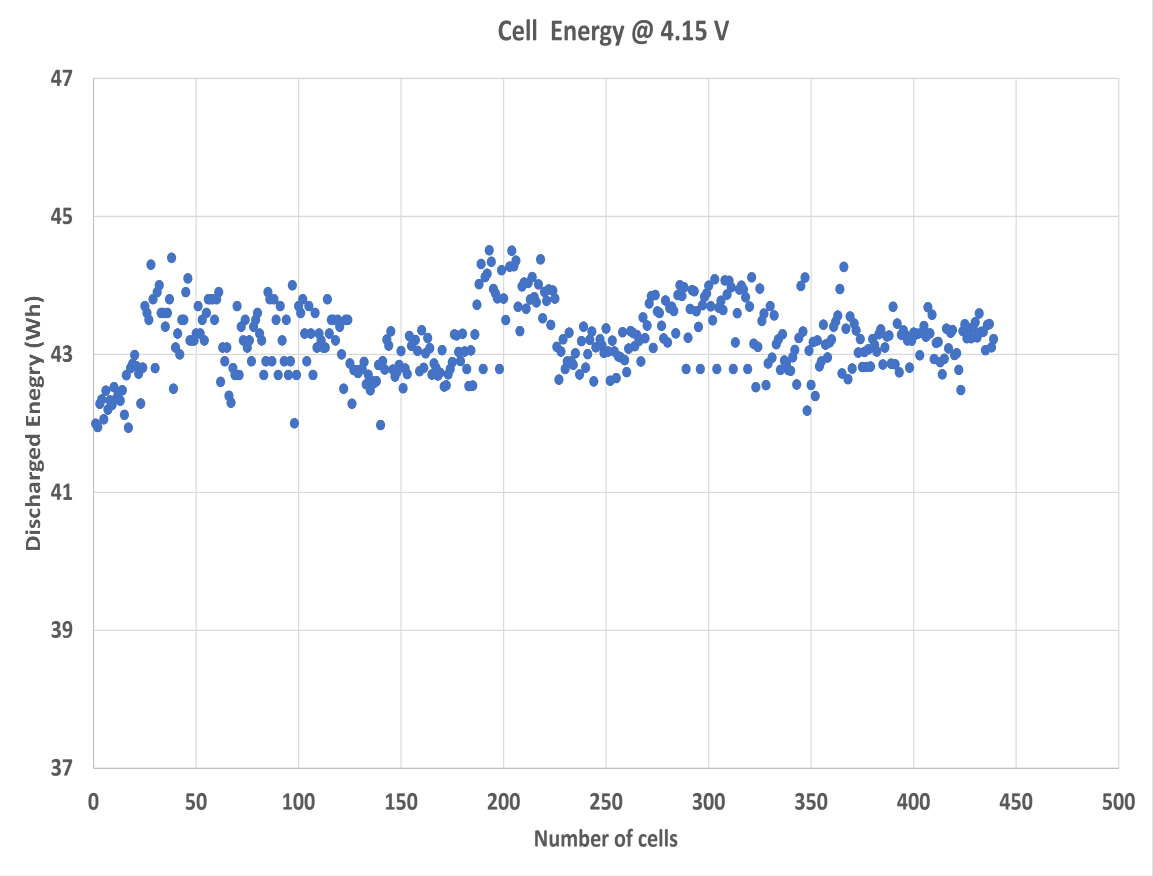
- 12.5 Ah and 46 Wh at 4.2 V, 20°C and C/2

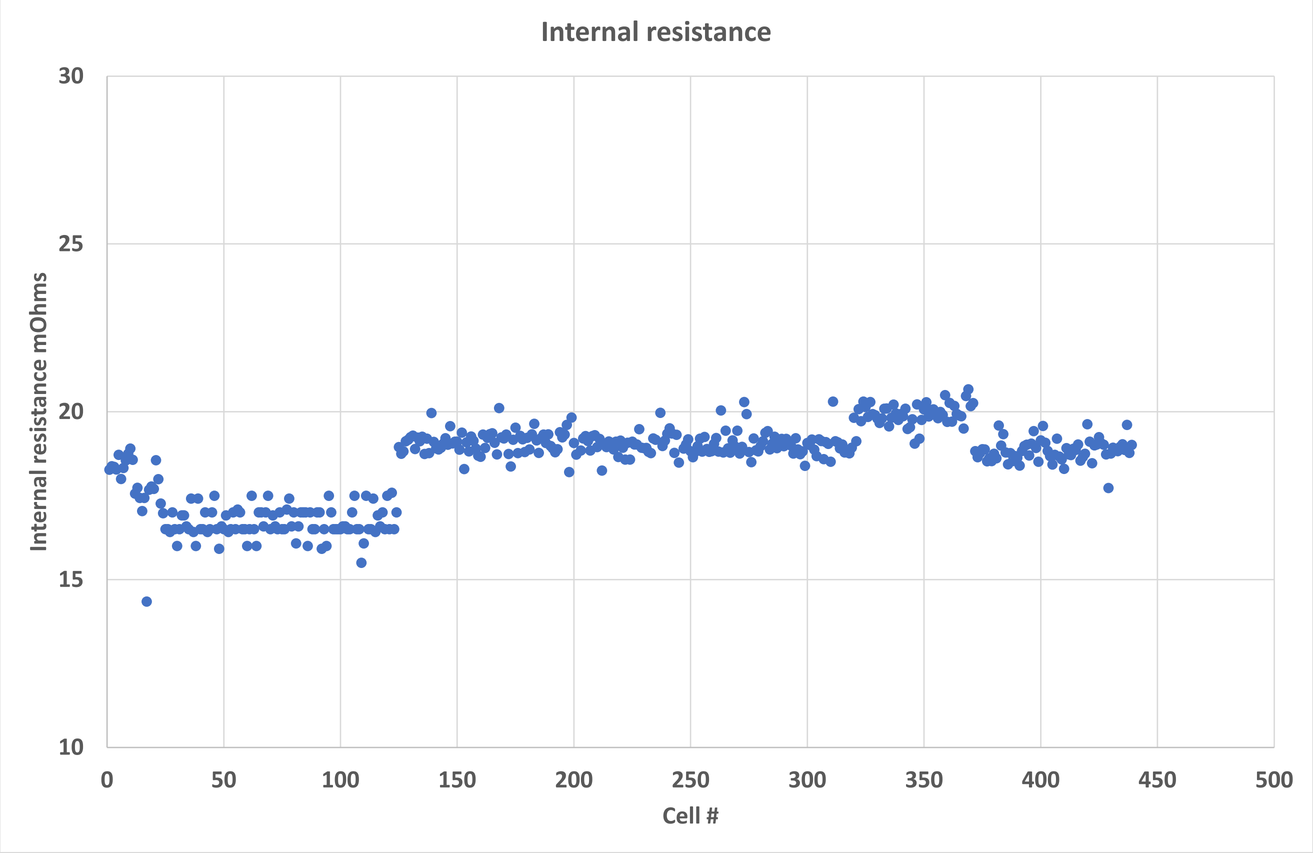


EM1 Cell Batch results

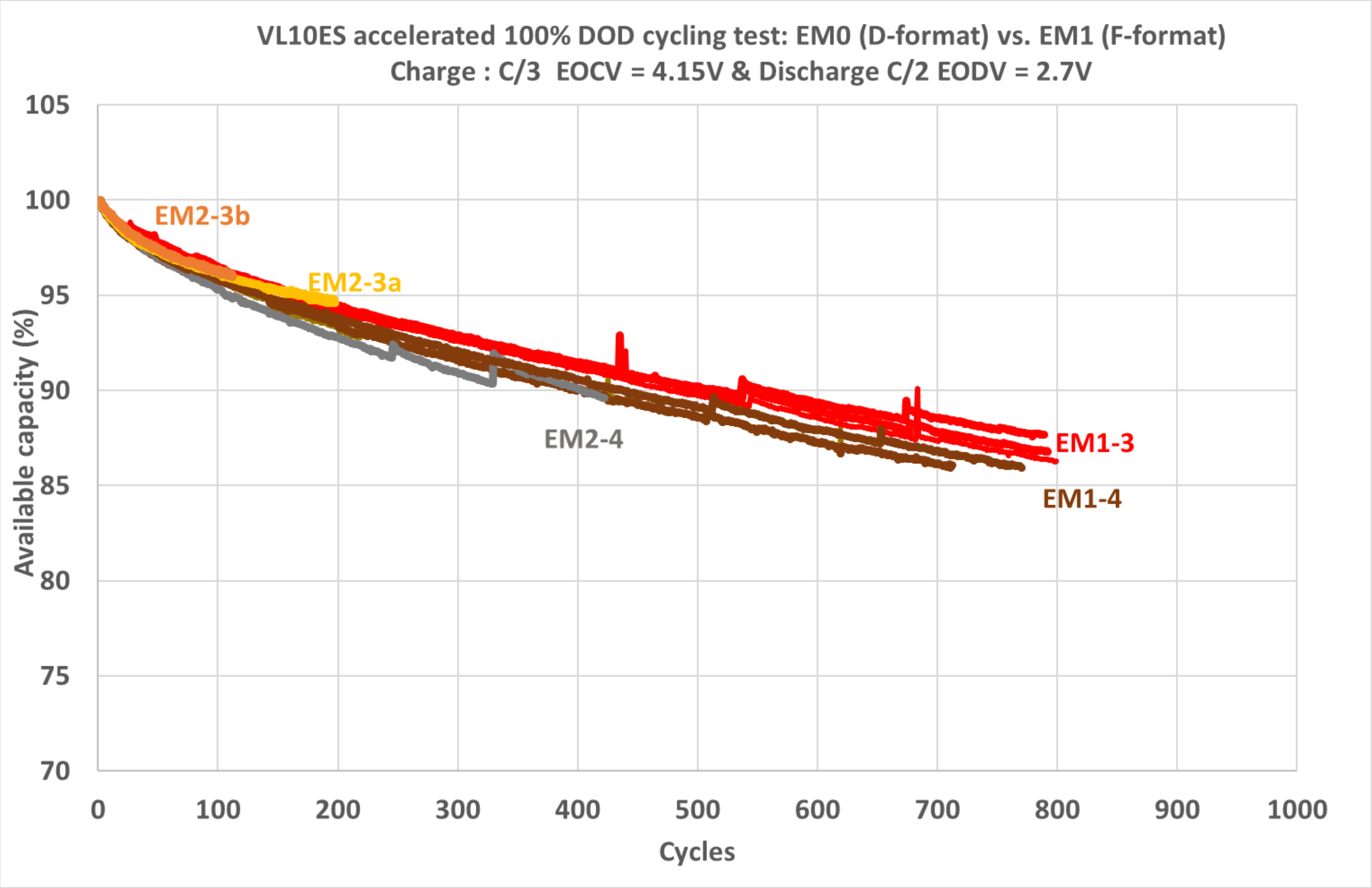
VL10ES EM1 batch performances (energy and internal resistance) :

- 3 lots already built





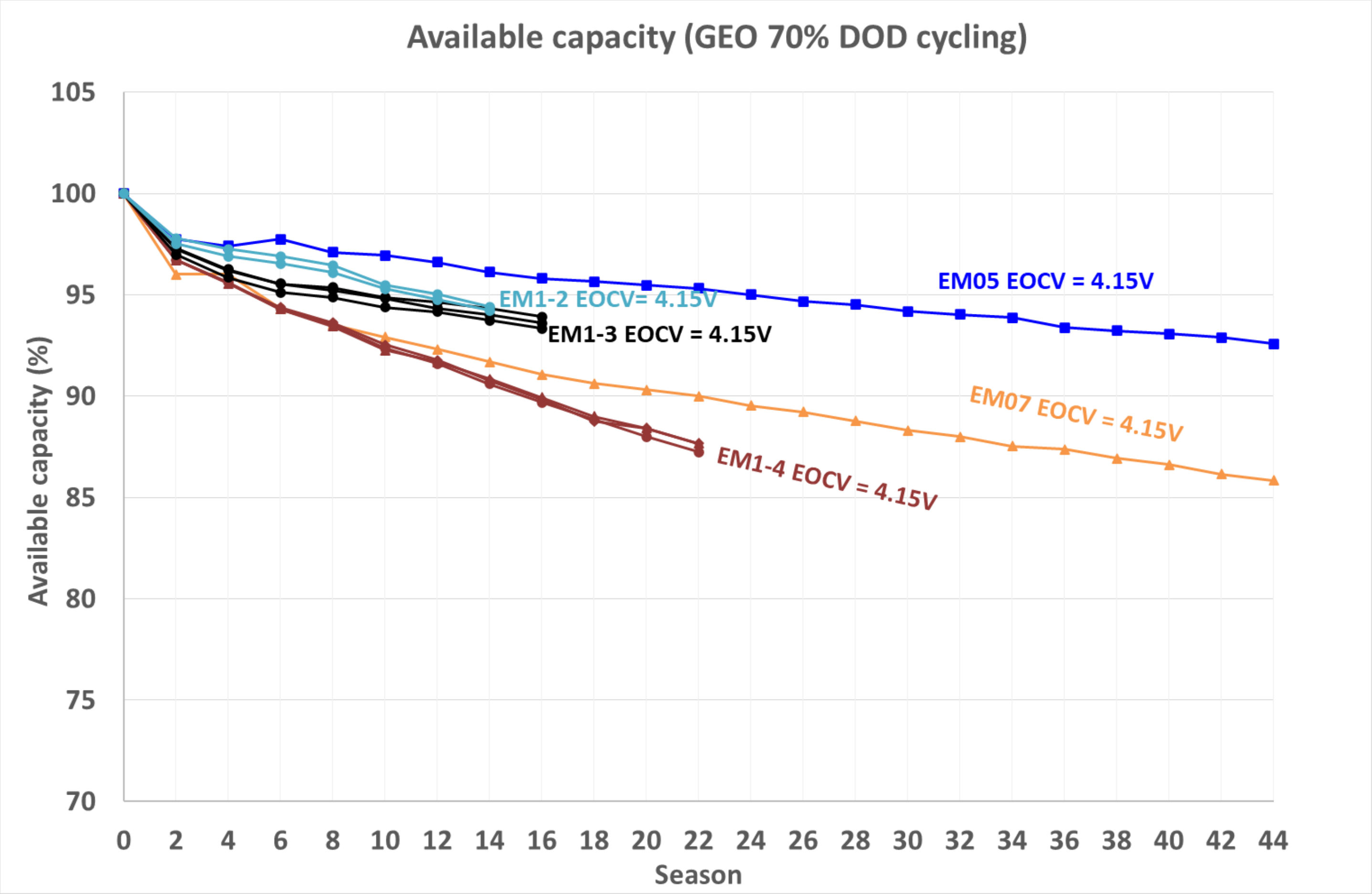
EM1 -100 % DOD cycling



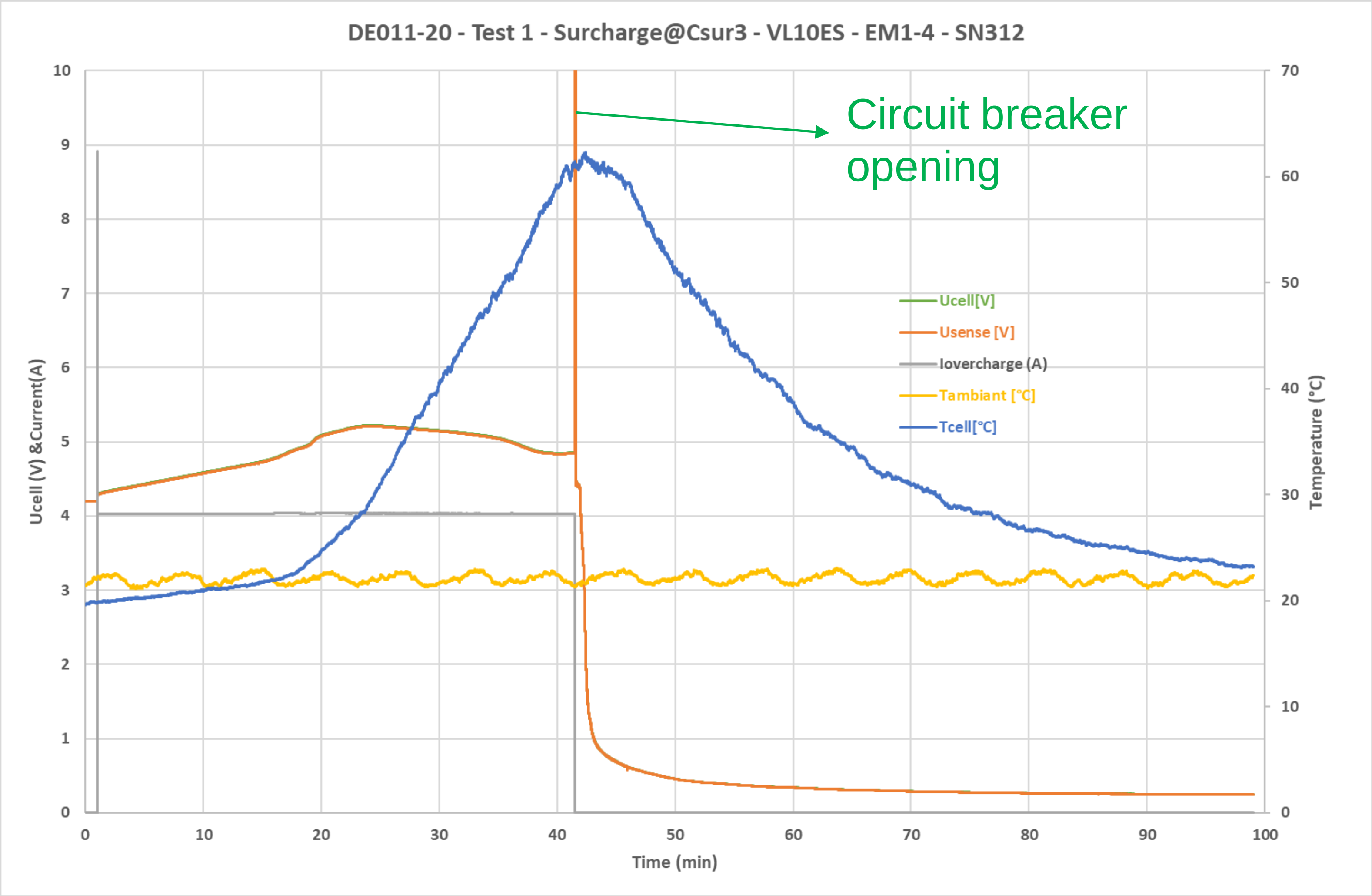
100 % DOD EM1 performances after 800 cycles in line with EM0

EM1 GEO Life tests

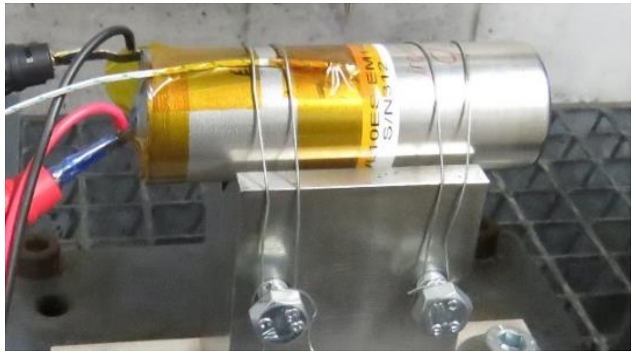
VL10ES EM1 same trend as per EM0 : EM1-2 vs EM05 and EM1-4 vs EM07



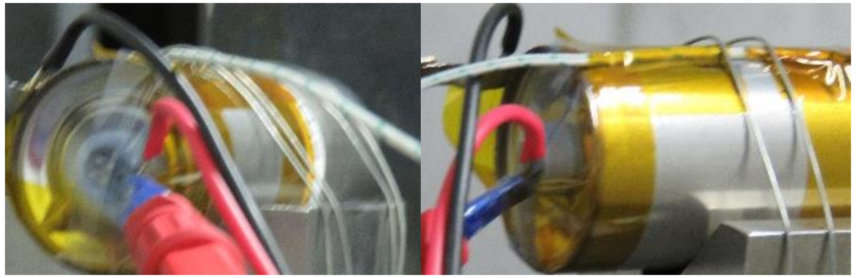
VL10ES EM1-4 : C/3 over-charge



Before test



After test



T < 65°C EUCAR2

VL10ES EM1-4 : pin test 100% SOC – 4.2V

Before test

After test

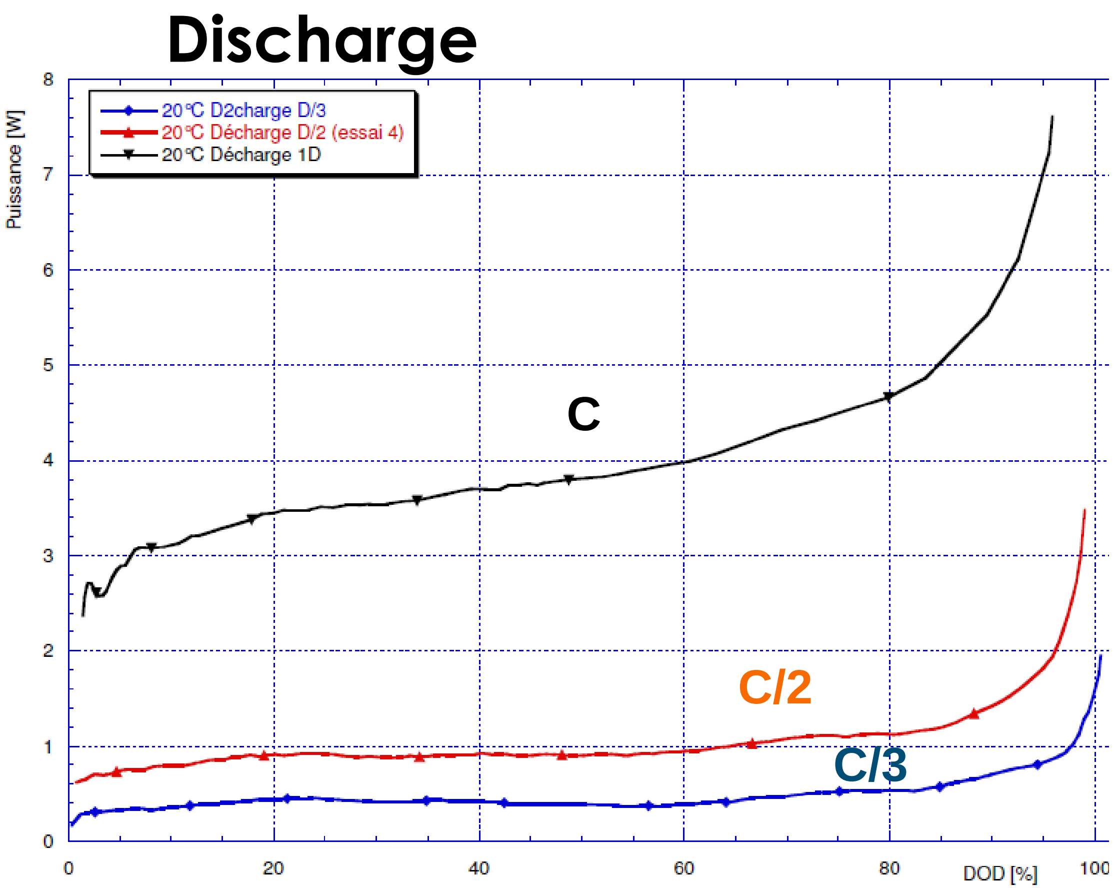
EUCAR5
2 vents opening
No cover ejection
No explosion

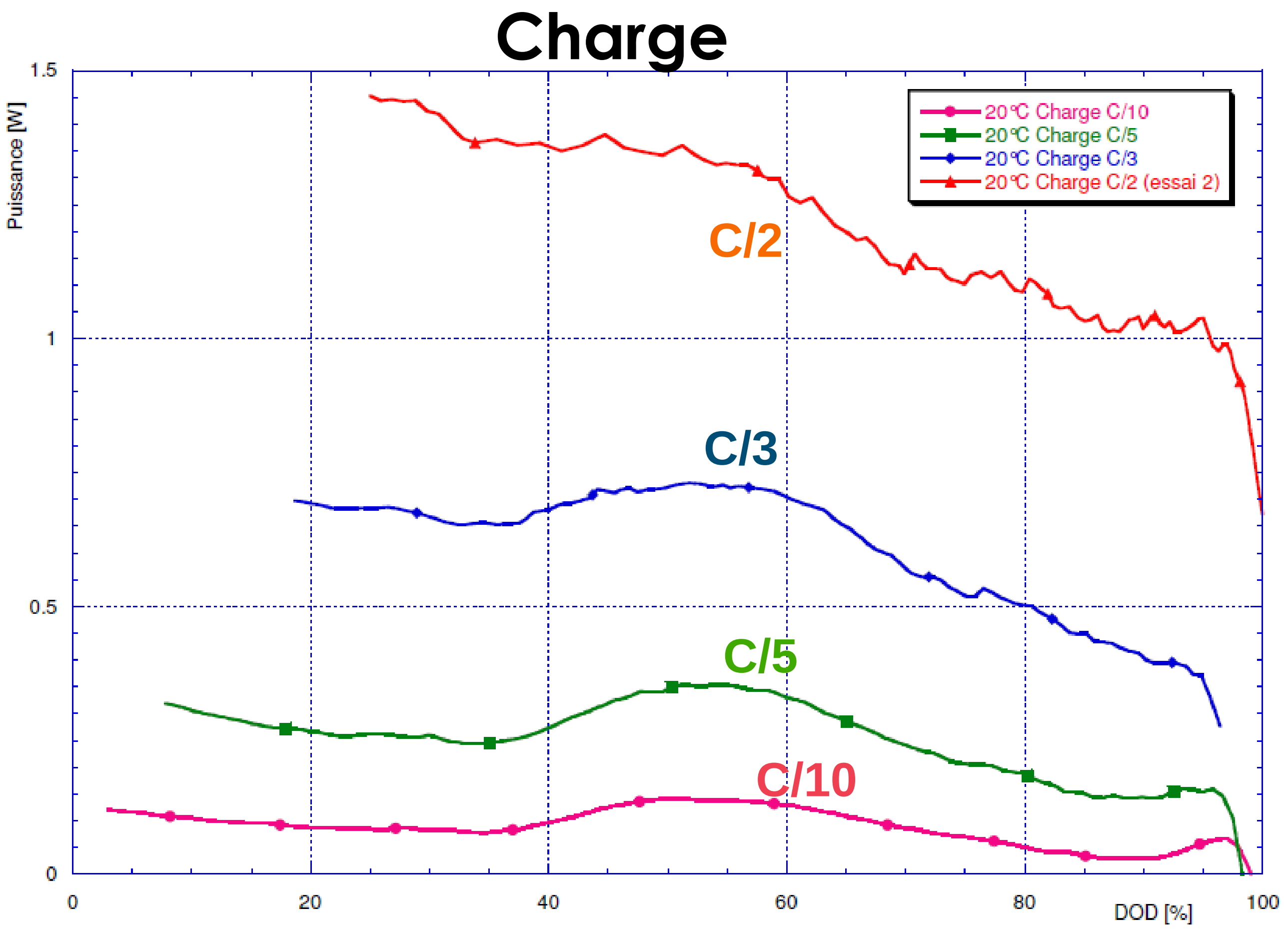
EM1/EM2 Safety Results

- **VL10ES safety as good as VES16 thanks to thick can, cover welding and 2 vents**

VL10ES	Crush test 50 & 100% SOC	C/3 & C over-charge	Impact test 100% SOC	Pin test 100%SOC	Pin test 50% SOC	Heating test	External-short 10mohm 100%SOC	Over-discharge
EM1-4 F format	100% SOC OK (2/2) EUCAR 2 50% SOC OK (2/2) EUCAR 2	C/3 OK (3/3) EUCAR 2 C OK (3/3) EUCAR 2	100% SOC OK (3/3) EUCAR 2 50% SOC OK (3/3) EUCAR 2	OK (3/3) EUCAR5	OK (3/3) EUCAR5	OK (3/3)	OK (2/2) EUCAR 3	(1/1 OK) in progress C/2 (10 cycles) at -0.5V
Tests results as good as VES16								

Cell Thermal dissipation @ 20°C

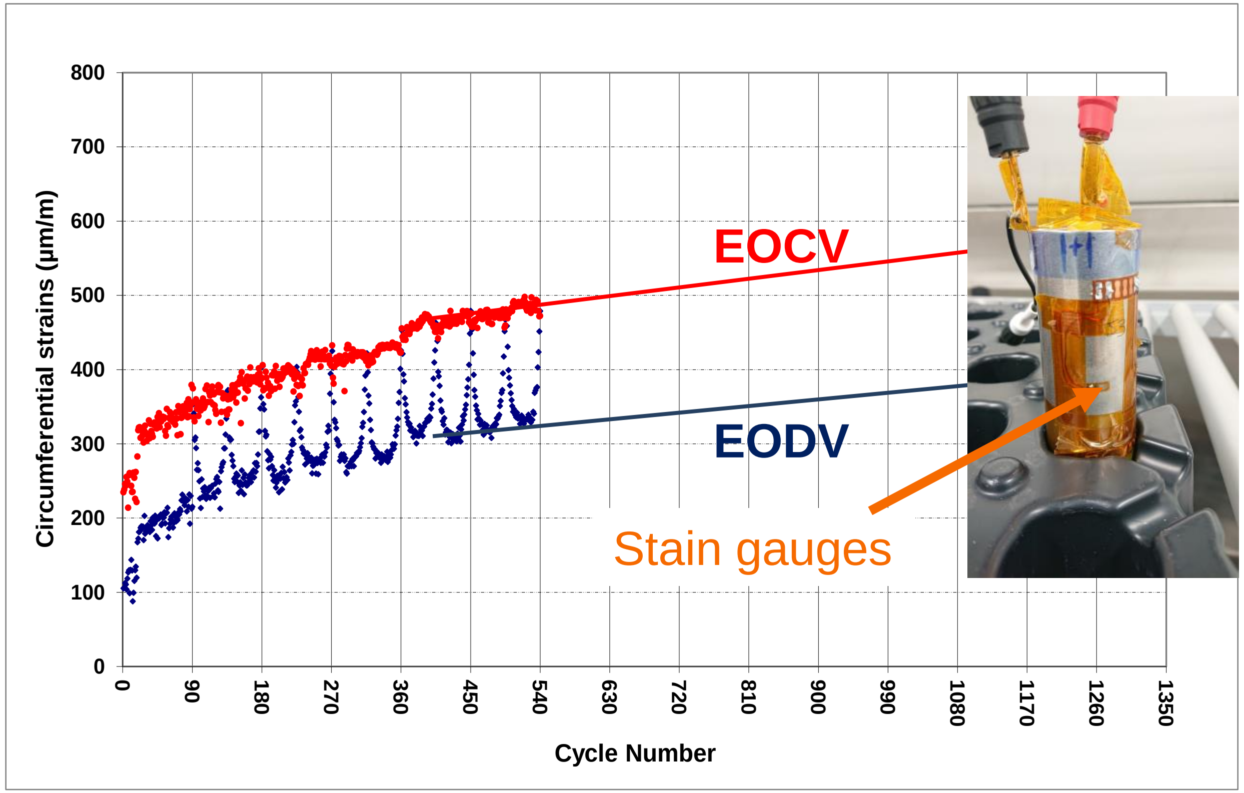


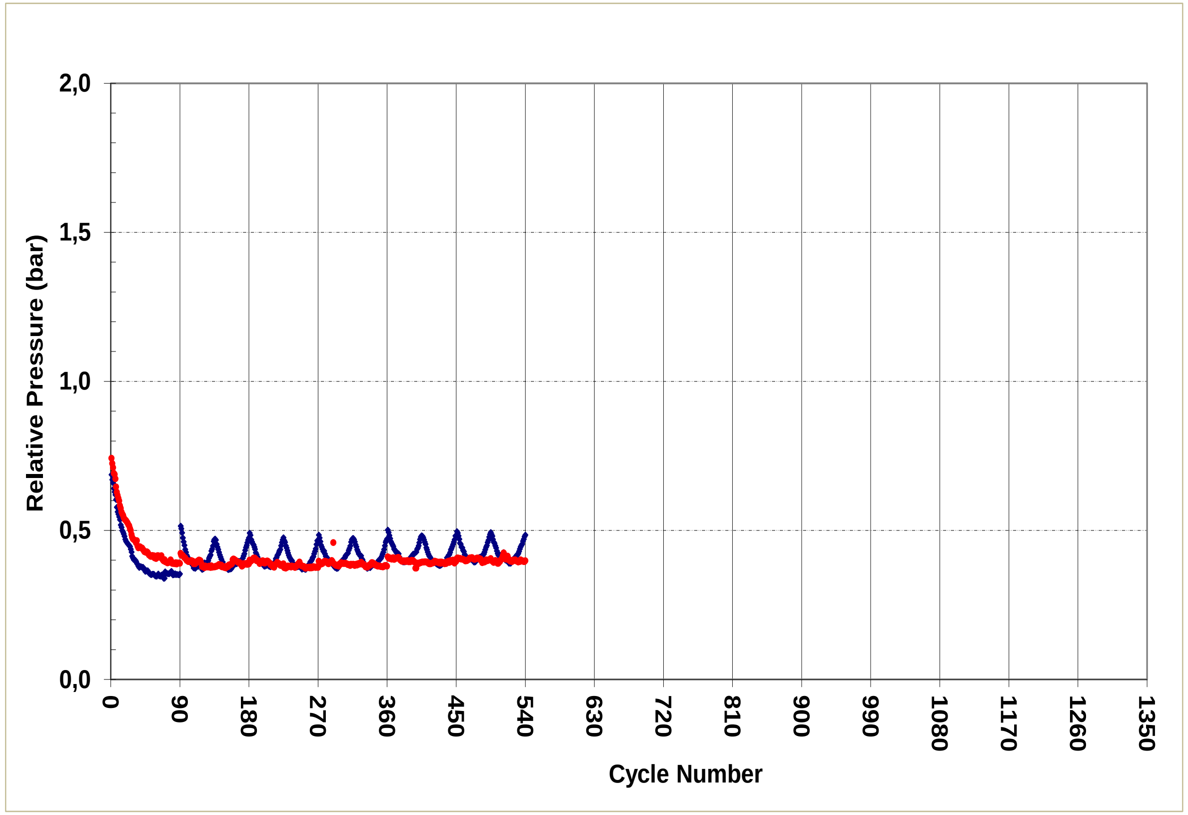


VL10ES thermal capacity : 186.6 J/°C

EM1-4 GEO cycling Strain gauges /Pressure Measurements

GEO 70 % DOD, 4.15 V @20°C





To check the EOL mechanical margins vs can material thickness after 12 GEO seasons:

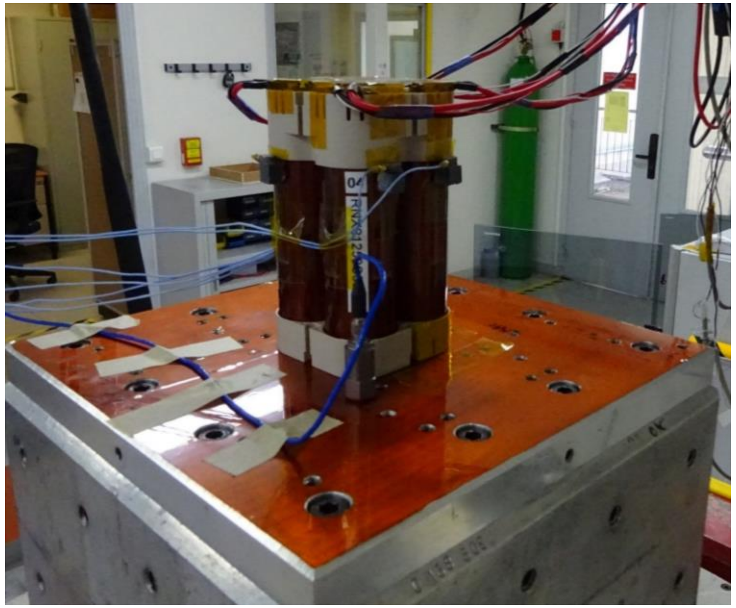
- EOC Strains under stabilization 600 µm/m
- No significant pressure variation

Mechanical environment test : Vibration tests on EM1-4

saft

Sine high level

Sweep rate: 2 oct/min per axis	Frequencies (Hz)	Levels	
		2 Oct/min	
⊥ to the mounting plane (Z) (cell axis)	5	1 g	9.94 mm
	20	22.5 g	14.0 mm
	30	27g	7.46 mm
	100	27g	0.67 mm



Random high level

On OZ	Frequencies (Hz)	Levels g²/Hz		g RMS (g)
⊥ to the mounting plane (Z)	20	0.140		31.34
3 min	50	0.400		
	80	0.587		
	400	0.587		
	750	0.446		
	1000	0.648		
	1500	0.648		

On OX/OY	Frequencies (Hz)	Levels g²/Hz		g RMS (g)
// to the mounting plane (X)	20	0.03		41.64
3 min	100	0.32		
	150	1.20		
	180	23.50		
	204	23.50		
	220	23.50		
	300	0.22		
	400	0.10		
	1000	0.10		
	2000	0.05		

Shock level

3 times per axis along a unique direction	Frequency (Hz)	Level SRS (g)
⊥ to the mounting plane (Z)	100	140
	1800	2500
	10000	2500

3 times per axis along a unique direction	Frequency (Hz)	Level SRS (g)
// to the mounting plane (X - Y)	100	140
	1800	2500
	10000	2500

No drift observed

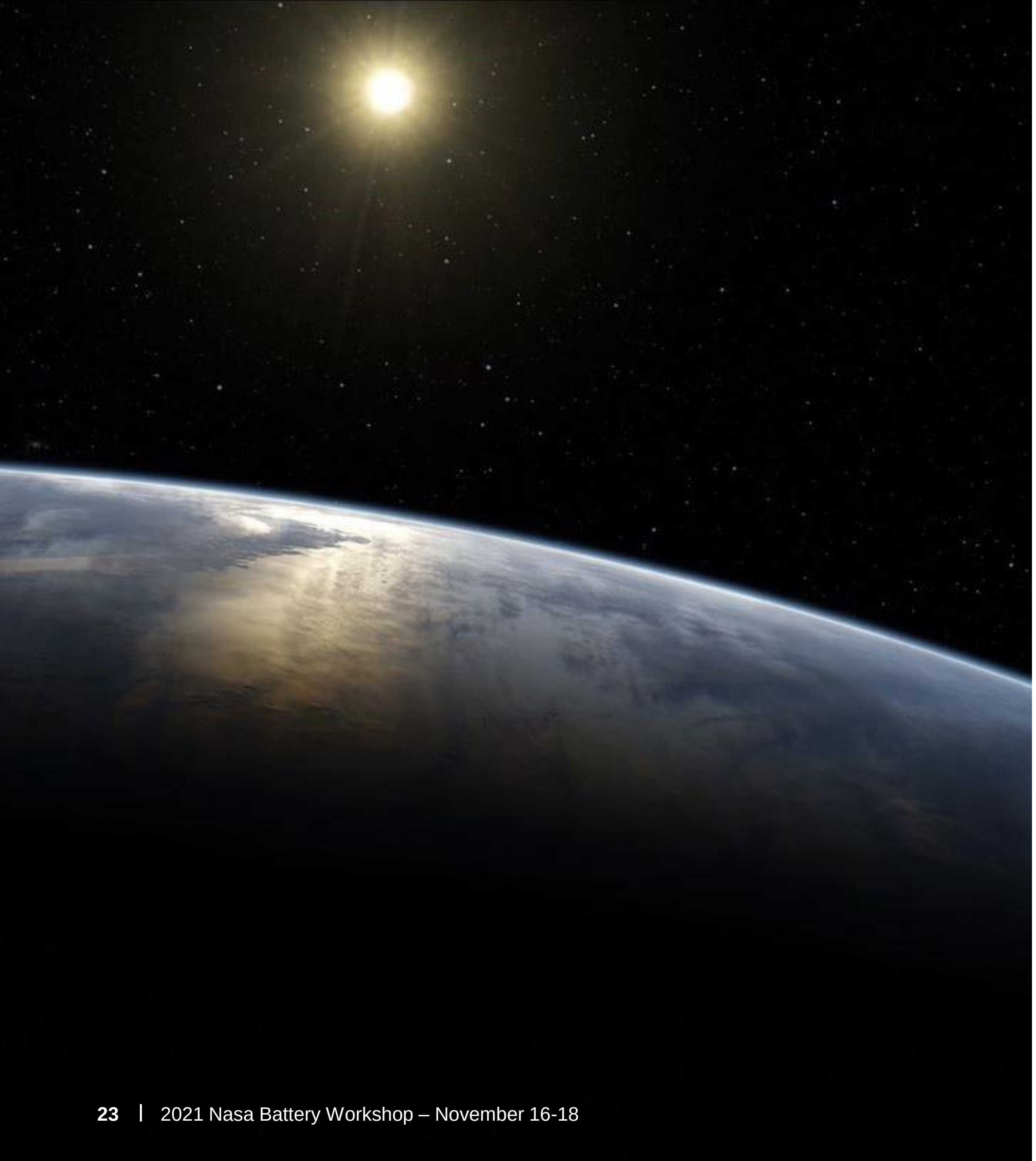
Criteria : Fr drift ≤ 5% for resonance frequencies over 300Hz

TotalEnergies

Cell qualification plan : same as per VES16/VL51ES

	*EM1	EM2	QM
Initial check up (Visual inspection, mass, dimension, chemical & Helium leak test, cells formation cycles, cell capacity/energy/IR test, leakage current & lithium excess)	✓	✓	✓
Lot Of Acceptance (DPA, lithium excess, burst test, inital capacity check-up test, DST cycling)	N/A	N/A	✓
Electrical test (Capacity/energy test @ different temperature, @ different C-rate, @ different pulses, @ different discharge power, *@ various EOCV, *self – discharge, *EMF measurement, cell impedance)	✓	✓	✓
Mechanical test (vibration , Shock, constant acceleration)	✓	✓	✓
Thermal & Vacuum tests (Thermal model, Thermal test and correlation, Thermal vacuum exposure, Maximum non-operating temperature exposure)		✓	✓
Radiation test		✓	✓
Safety test (overcharge, overdischarge, reversal test, external short circuit, drop test, impact test, overtemperature, internal short circuit (Pin test), crush test, Arc test, burst test with & without vent)	✓	✓	✓
Lifetime test (Real time LEO test, accelerated LEO test, real time LEO test with radar pulse, accelerated GEO, 100% DOD cycling)	✓	✓	✓
UN transportation			✓

TotalEnergies



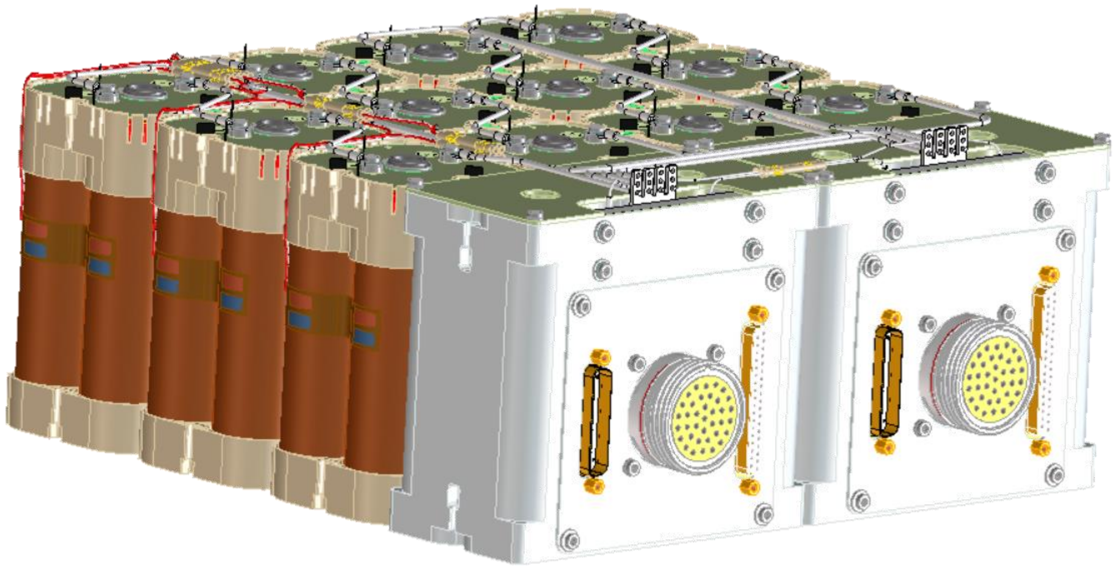
Battery Design

Battery concept: 4 cells base block

INDEPENDENT BLOCK	• Independent electrical, mechanical and thermal interface
AUTONOMOUS ELECTRONICS	• Each block includes its own autonomous electronics
ASSEMBLY INNOVATION	• Improved packaging factor • Lean manufacturing and easy repair
MODULARITY	• Optimize the spacecraft footprint • Minimize non-recurring activities from one program to another

Battery Assembly

12S4P (EM1)

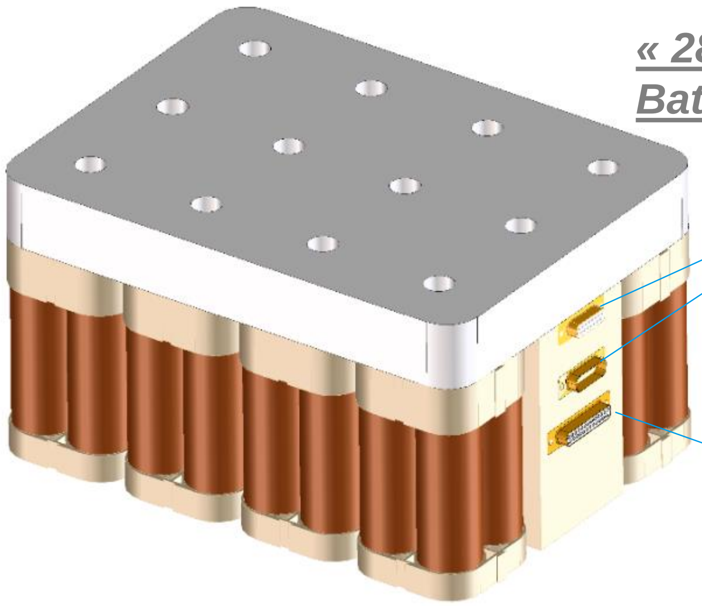


Negative power / Positive power, telemetries with redundancy

Modularity voltage and energy – Selfstanding pack – Assembly keying – Easy ground maintenance – Electrical interface easily configurable – Minimizing NRE effort – Maximizing packing factor 1.25

Battery concept – LEO application

Battery design for cycling up to 30% DoD for 12 years LEO mission.



Electrical characteristics	8S5P VL10ES
Nameplate energy (Wh)	1840
Nameplate capacity (Ah)	60
Recommended cycling End of Charge voltage (V)	33,2
Maximum End of Charge voltage (V)	33,6
Physical characteristics	
Lenght (mm)	280
Width (mm)	210
Height (mm)	157
Weight (kg)	11

- SP topology adapted to low capacity cells with internal safety device adapted to **unregulated bus**
- VL10ES equipped with autonomous balancing based on to the Simplified Balancing System qualified on VES16

TotalEnergies

Battery qualification plan

	EM0	EM1	EM2	QM	Mock-up
Functional characterisations (Functional check-up, internal resistance, balancing function check-up, initial and final charge retention, stored energy at several temperatures, impedance, balancing demonstrations,…)	✓	✓	✓	✓	
Environmental tests (Vibrations, shocks, charge retention, corona tests, leak tests, magnectic moment measurement, EMC test, impedance,…)		✓	✓	✓	
Life tests (GEO Life Tests accelerated battery level)				✓	
Safety tests (Internal Soft Short test, external and internal Short Circuit tests, overcharge)					✓

Conclusions

Conclusions

- VL10ES EM's performances are in line with expected targets :
  - **Specific energy >220 Wh/kg**
  - LEO/GEO cycle results and life with **low fading and stable internal resistance**
  - Environments : mechanical, thermal, radiations
  - Safety
- Battery development on schedule

First LEO and GEO VL10ES satellite batteries contracts

Acknowledgements

- Saft Nersac, Cockeysville and Poitiers VL10ES development teams

- ESA and CNES

Thank you