VL10ES Saft High Energy Cell and Battery Qualification Status

Dr. Y.Borthomieu, Dr. JP.Peres and Dr. C.Ma

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Agenda

1. Objectives and adressed markets
2. Cell and battery concepts
3. Status and development phases
4. Conclusions

VL10ES Saft High

OBJECTIVES AND ADRESSED MARKETS

Objectives and adressed markets

Price reduction

- Reduce **the cell and battery price**
- Address LEO, GEO, MEO, constellation markets
- Less cells in large batteries vs VES16

Technical performances

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

Safety ensured

- Compatible with Safety Launch Pad
- Robust **stainless steel casing**

GEO satellites
Low to high power
5 to 30 kW

Standard LEO
&
Constellation LEO satellites
With long lifetime

Performances objectives – compared with Saft VES16

CELL TYPE	VES16 (D-size)	VL10ES (F-size)
Dimensions (Ø x H)	33 x 60 mm	**33 x** 103 mm
Weight	≤ 115 g	**210 g (tbc)**
Volume	0.051 dm^3	0.086 dm^3
Voltage range	2.7 V - 4.1 V	2.7 V - 4.2 V
Nominal capacity	4.5 Ah @ 4.1V, 20°C	**> 12 Ah @ 4.2V, 20°C**
Nominal energy	16 Wh @ 4.1V, 20°C	**> 46 Wh @ 4.2V, 20°C**
Specific energy	> 140 Wh/kg	**> 220 Wh/kg**
Internal resistance	≤ 35 mΩ @ 20% DoD	≤ 22 mΩ @ 20% DoD / TBC
Operating temperature	+10°C / +40°C	+10°C / +40°C
Mechanical design margins	EWR & ECSS compliant	EWR & ECSS compliant

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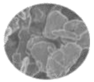
CELL AND BATTERY CONCEPTS

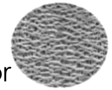
Cell concept for high specific energy, long life and safety

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



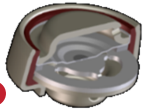
Symmetric double vent safety device
for thermal runaway management

Specific separator
Electrolyte reservoir for long range cycling



Positive electrode
Innovating densification concepts to increase specific energy

Electrolyte
Formulation optimization for LEO



Circuit breaker
Similar to VES16
Increased robustness in T°

Specific Cell filling & formation
Optimal impregnation and limitation of self-discharge

Thick Stainless-steel casing
Welded cover

Battery concept: 4 cells base block

Autonomous electronics

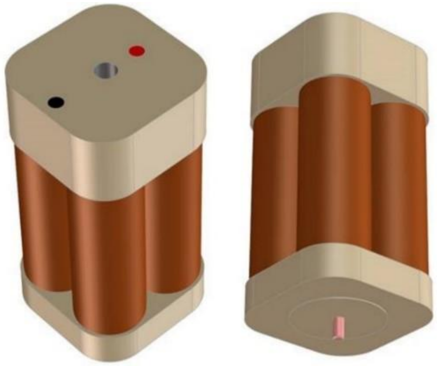
Each block includes its own **autonomous electronics** (4 Simplified Balancing System per block)

Assembly innovation

Each block is self maintained

Independent block

With independent electrical, mechanical and thermal interface allowing easy replacement

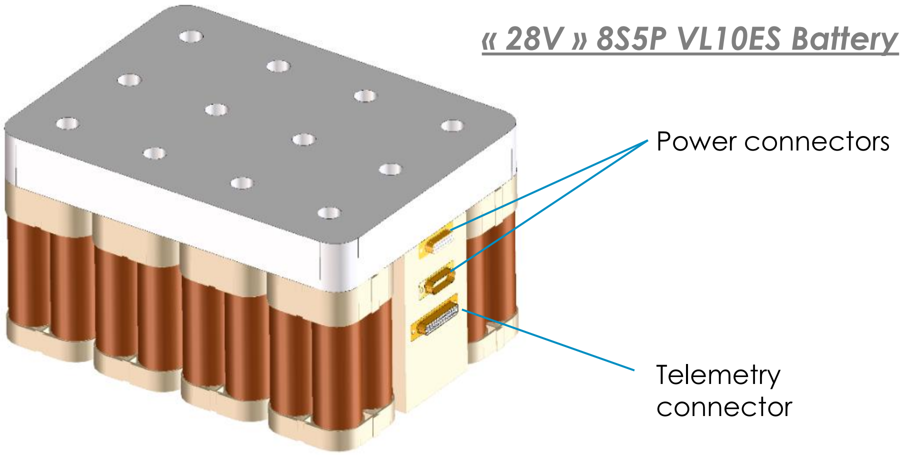


Modularity

Blocks are mechanically electrically linked to each other to reach larger S-P configurations

Battery concept – LEO application

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

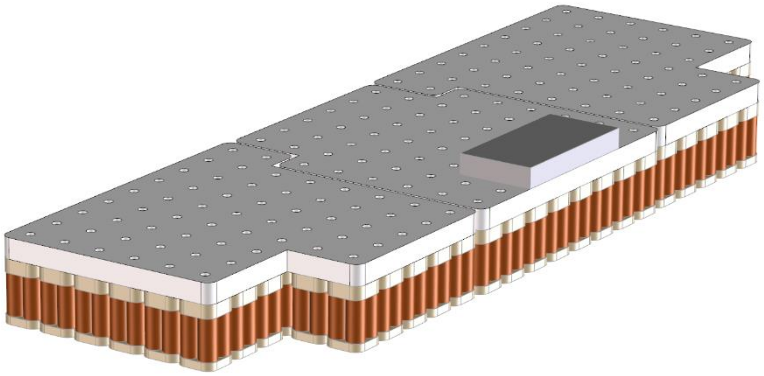


Electrical characteristics	8S5P VL10ES
Nameplate energy (Wh)	1840
Nameplate capacity (Ah)	60
Recommended cycling End of Charge voltage (V)	33,2
Maximum End of Charge voltage (V)	33,6
Physical characteristics	
Lenght (mm)	280
Width (mm)	210
Height (mm)	157
Weight (kg)	11

- 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

Battery concept – GEO application

Battery design for 70% DoD , 18 years GEO mission.



« 150 V »   36S20P VL10ES Battery

Electrical characteristics	36S20P VL10ES
Nameplate energy (kWh)	**33,1**
Nameplate capacity (Ah)	240
Recommended cycling End of Charge voltage (V)	149,4
Maximum End of Charge voltage (V)	151,2
Physical characteristics	
Footprint of modules 1 & 2 (mm)	632 x 562 x 160
Footprint of module 3 (mm)	562 x 562 x 160
Weight (kg)	**190**

- **Configuration for GEO platforms specific requirement from 3 to 30 kW and 50, 100 or 150 V buses.**
- SP or SPS topology adapted to low capacity cells with internal safety device

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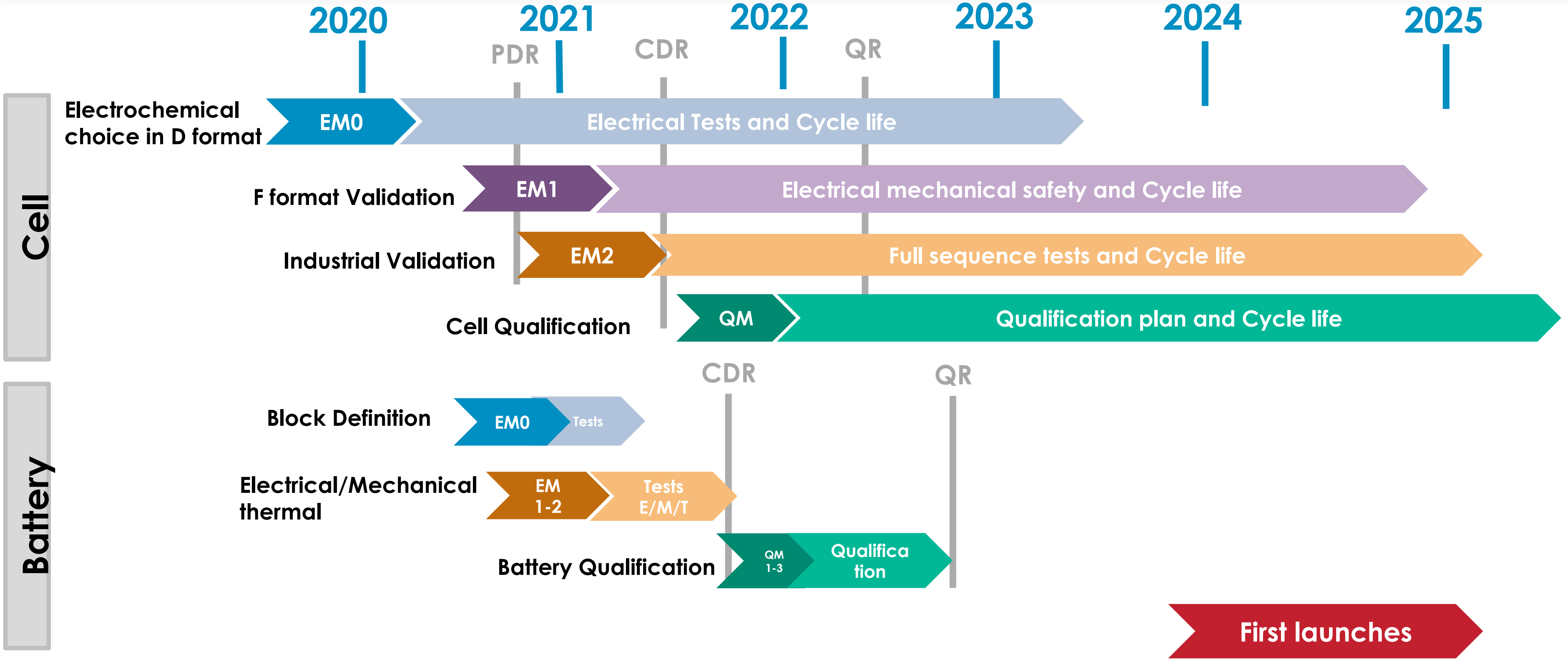
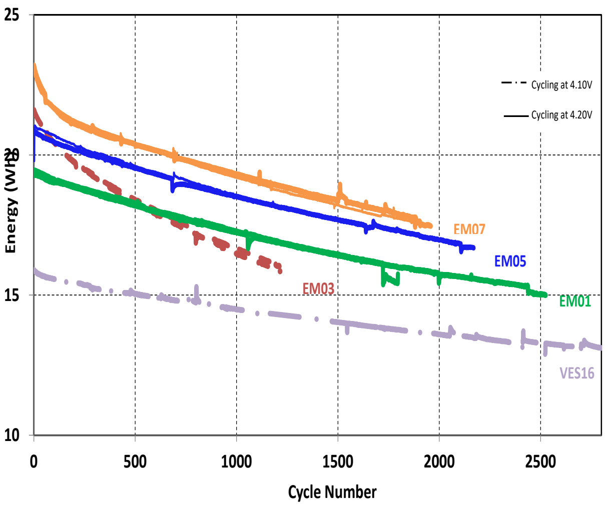
DEVELOPMENT PHASES & STATUS

Cell and Battery Development status

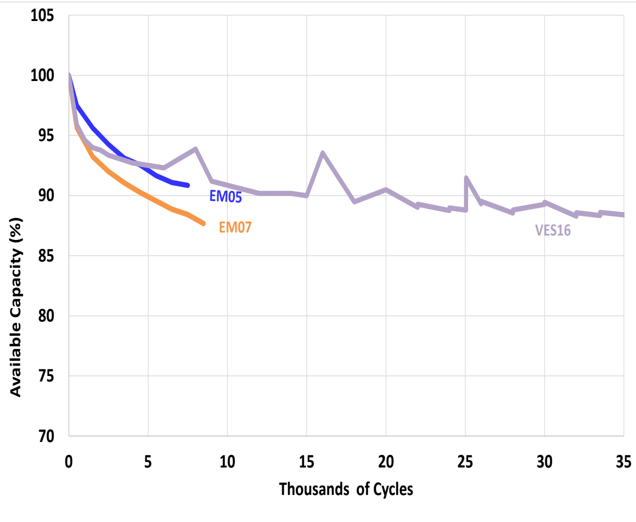


Electrochemistry development: EM0 (D-format) cycling results

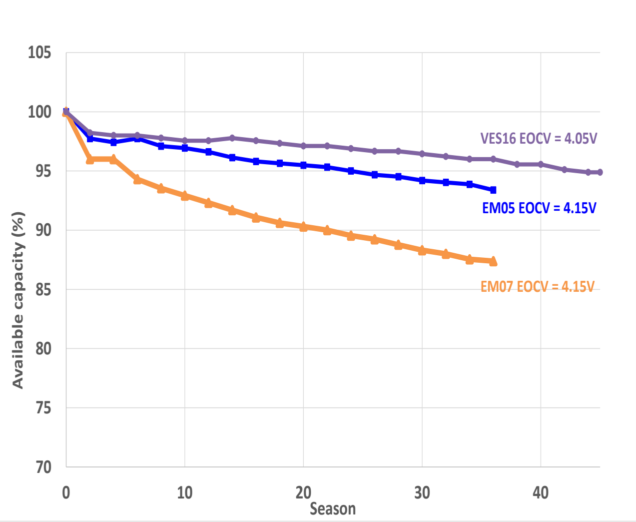
Accelerated 100% DOD cycling C/3-D/2



LEO cycling at 30% DOD



Accelerated GEO cycling at 70% DOD

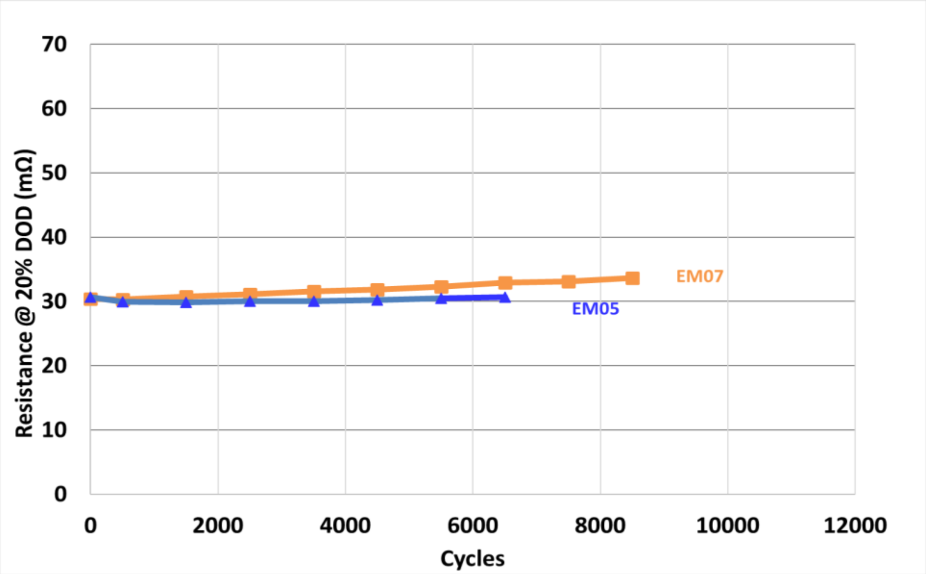


Results : 14 electrochemitry combinations tested / 2 families selected for EM1

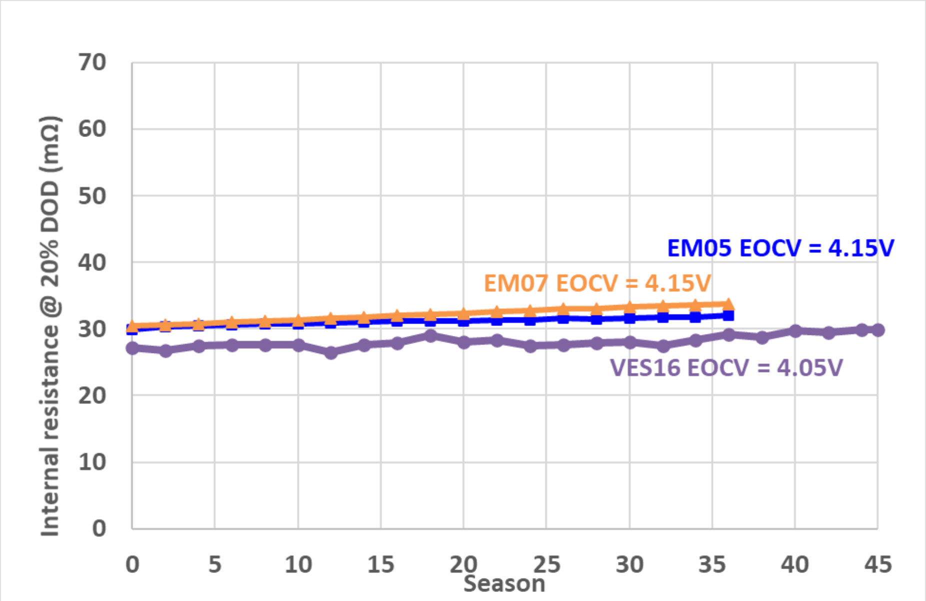
- LEO cycling: Energy loss of EM0 are showing similar trends as VES16 in LEO 30% after 8500 cycles and answer to 12 years missions
- GEO cycling: EM0 chemistry demonstrated 36 GEO seasons (18 years) with limited fading

EM0 (D-format) internal resistance results

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



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



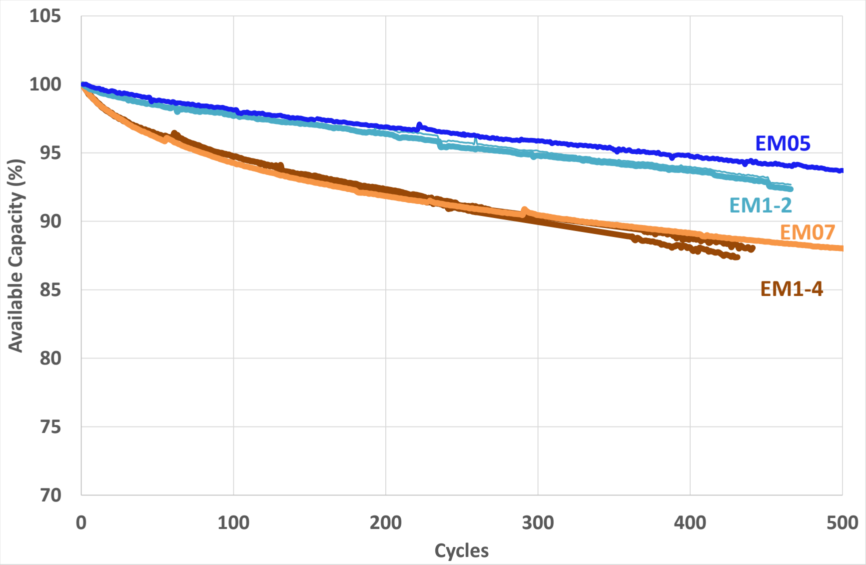
Observations:

Stable internal resistance, answering to both LEO and GEO missions

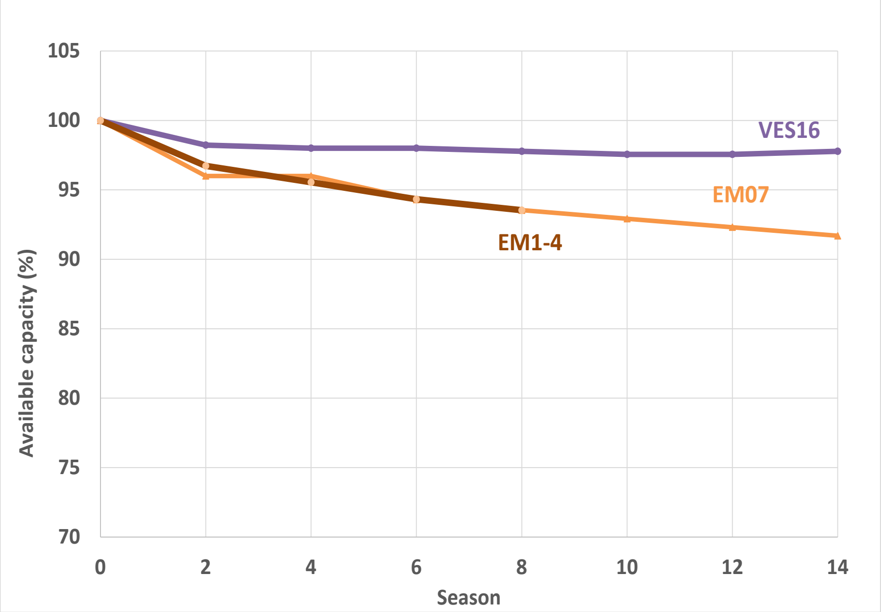
EM1 Life tests

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

- after 500 cycles @ 100 % DOD



after 8 GEO seasons @70%DOD



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EM1 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 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			✓

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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)					✓

Development Status

- **Cell/batterie PDR's successfully held in December 2020**
  - EM1 tests confirmed the specific energy **220Wh/kg**,
  - Cycle life : preliminary results same as per EM0
  - 4 cell packages design justifications

Done

- **Cell CDR scheduled in Mai 2021**

Next steps

- **Cell /batterie QR planned in Mars-April 2022**

CONCLUSIONS

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Conclusion

- VL10ES development : **QR confirmed first semester 2022**
- EM0 and EM1 performances in line with expected targets :
  - **Specific energy >220 Wh/kg**
  - LEO/GEO cycle results and life with **low fading and stable internal resistance**
  - Safety
- Battery development on schedule

First LEO and GEO VL10ES satellite batteries contracts have been already signed

Acknowledgements

- Nersac, Cockeysville and Poitiers VL10ES development teams members

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Merci
Vielen Dank
תודה, תודה לך!
Dekuji
Thank you
谢谢
Tack