Saft Gen6-VL51ES Update

Drs Chengsong Ma, Yannick Borthomieu, Eric Ligneel

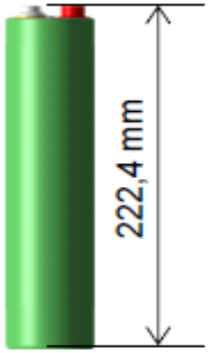
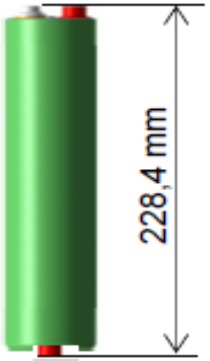
April 28, 2022, Space Power Workshop

Saft Li ion in Orbit Heritage and Reliability

- **344 satellites in-orbit with Li-ion (GEO, MEO & LEO) : 329 operational**
  - *More than **2,1 Billion** of cell hours with no failure or deviations*
  - *Total over **3,6 MWh** in-orbit with 601 batteries and more than **45 000 cells in orbit***
- **188 GEO satellites Launched today with VES/VL technology (8 launch failures) + 1 Moon Mission :**
  - ***W3A** launched 18 years ago : 14th March 2004 with VES140*
  - *12 satellites with VL48E : AEHF SV5 GOES R*
  - ***OPTUS-D3** launched 21st Aug 2009 with VES180 , and currently 71 satellites with VES180*
  - *First launch with VL51ES Sept 21*
- **5 MEO satellite flying with VES technology:**
  - *Giove-B flying since April 08*
  - *4 Galileo IOV launched in Nov 2011 with VES180*
- **149 LEO satellites are today in-orbit with VES or MPS Li-ion technologies:**
  - ***TeLEOS 1** first satellite launched with VES16 battery , Upmsat, Esail, Cheops, Argos, Paksat 1a, Eucropis and Nexsat1*
  - *75 first **Iridium Next satellites** with VES16 batteries*
  - *6 with VES100 Batteries: Calipso, Corot, Jason, SMOS, SRE1, Kompsat 3 (with ISIS electronic), Gokturc2*
  - *51 with MPS technology: Agile, SSETI, Proba-2, NanoSat-1B, CanX-2, NTS, OG2 (17), Techdemosat, M2M*

Design overview vs VES180

- Same diameter but shorter compared to VES180SA/VL48E (same cell pack design)
- Tabless design
- Same side terminals with easier connection versus VES180S/VL48E

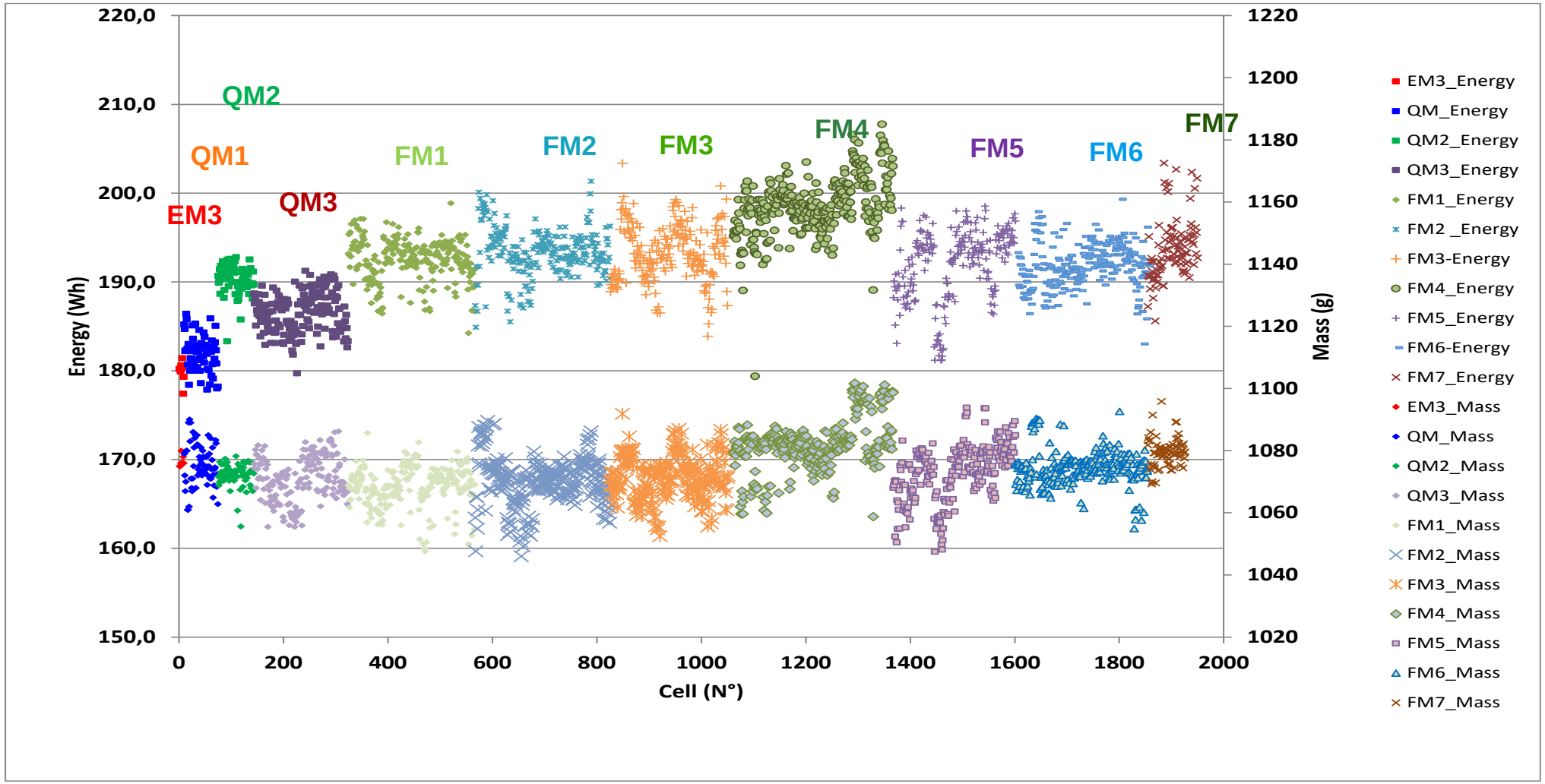
Configuration	2 same side terminals as baseline	2 same side terminals with optional bottom terminal	VES180 SA
Interface			

Main characteristics

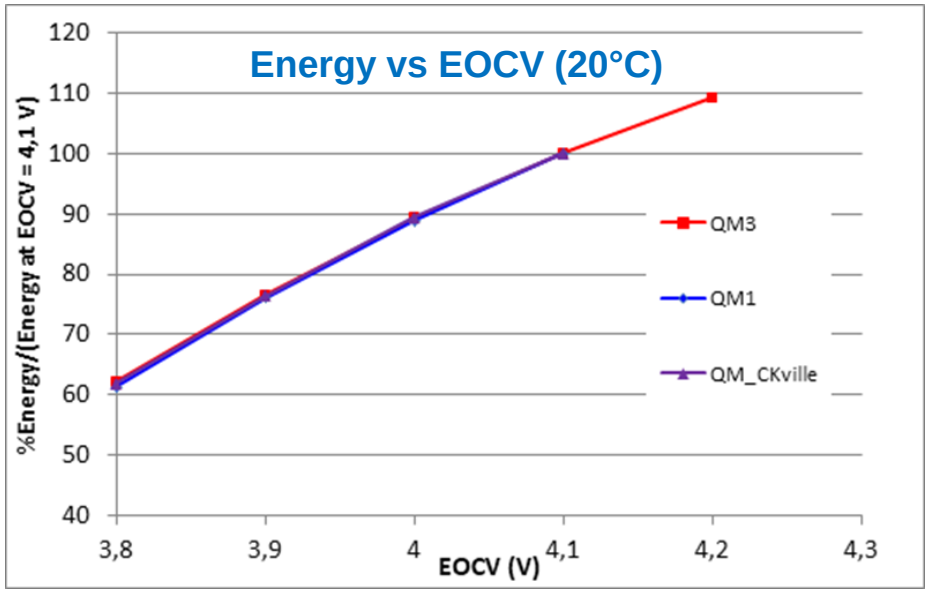
	VES180SA/VL48E	VL51ES
Average capacity (Ah) @ 4.1V	48 Ah	**51 Ah**
Average energy (Wh) @ 4.1V	175 Wh	**186 Wh**
Average Weight (g)	1128 g	**1079 g**
Voltage range (V)	2.7-4.1 V	**2.7-4.1 V**
Average Specific Energy (Wh/kg)	158	**175**
Internal resistance (mΩ)	2.5 mΩ	**1.5 mΩ**
Operating temperature (°C)	+10 to +40 °C	**+10 to +45 °C**

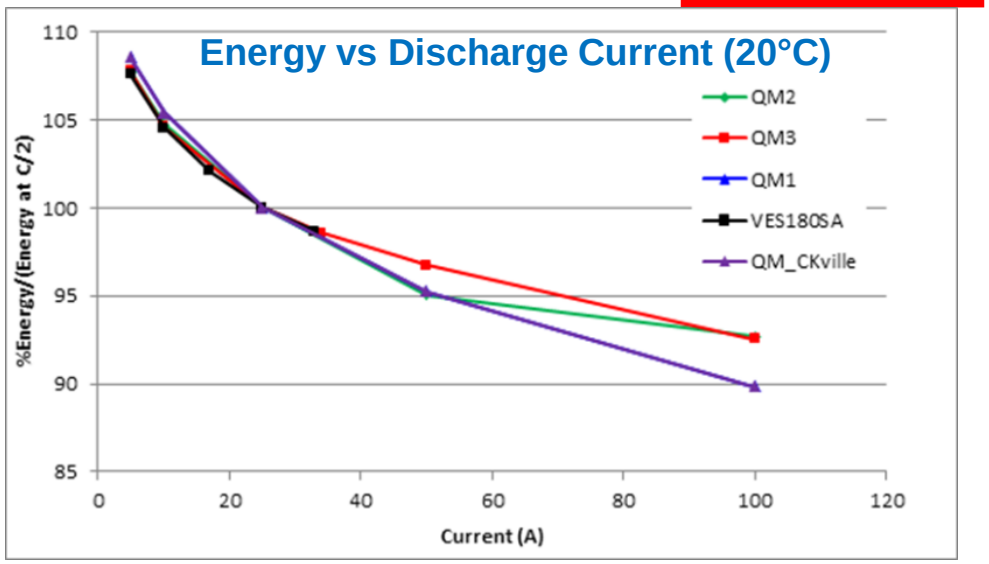
QM/FM Nersac Acceptance test results

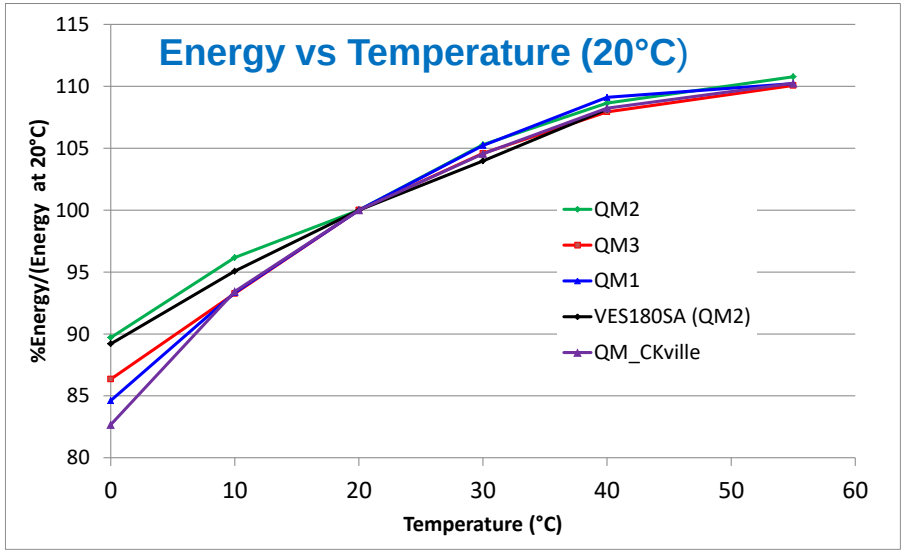
Energy and mass trend including 7 large flight batches under evaluation

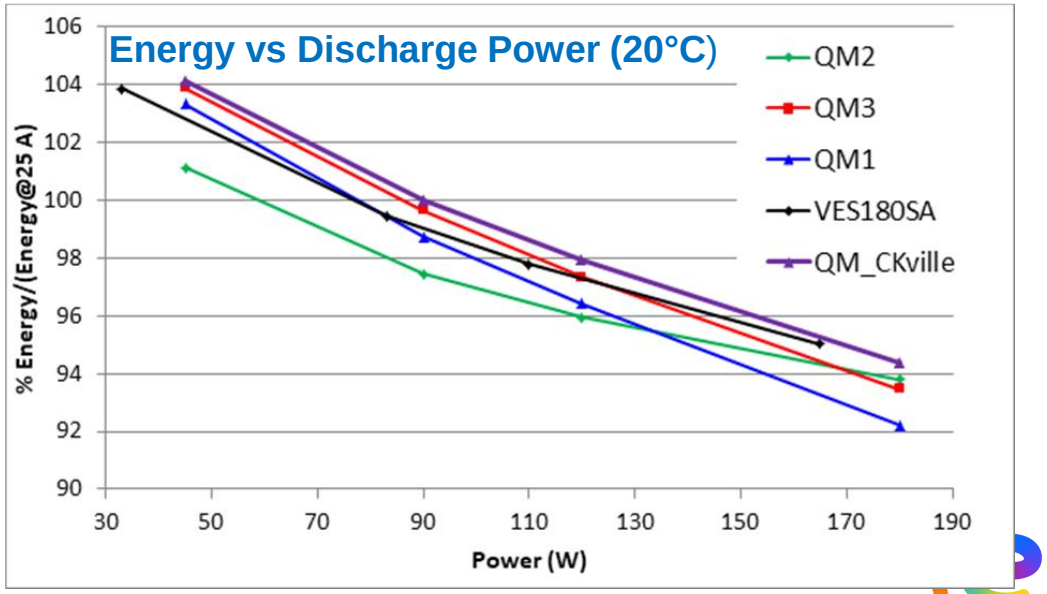


QM BOL Electrical tests vs EOCV, Temperature, Discharge Current and Power









VL51ES Li-ion Cell Thermal Qualification results

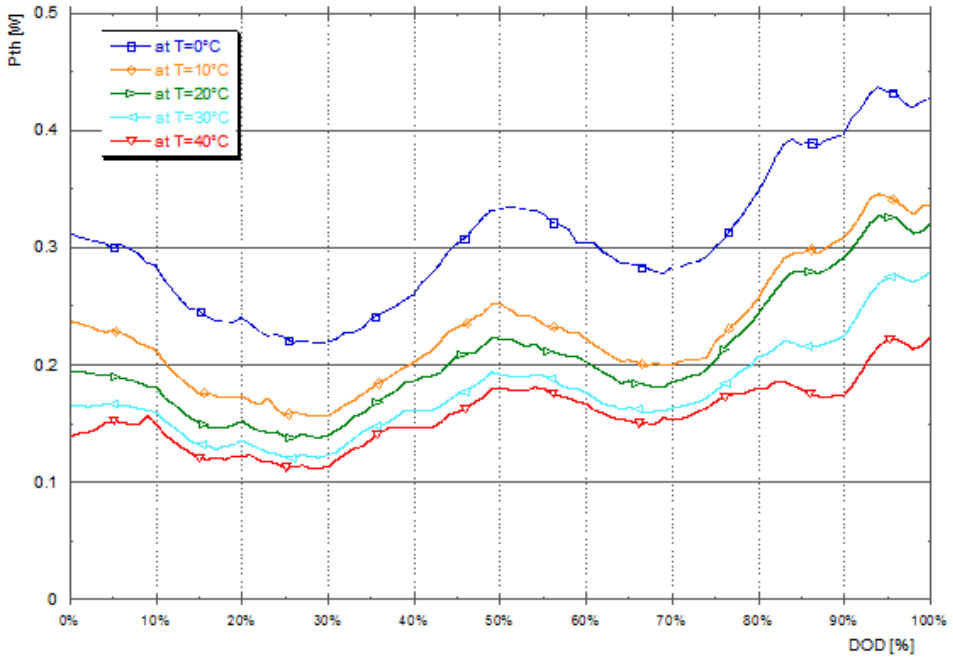
- VL51ES Li-ion cell thermo-electrical model was established ref. **S0832-16 Issue2.**

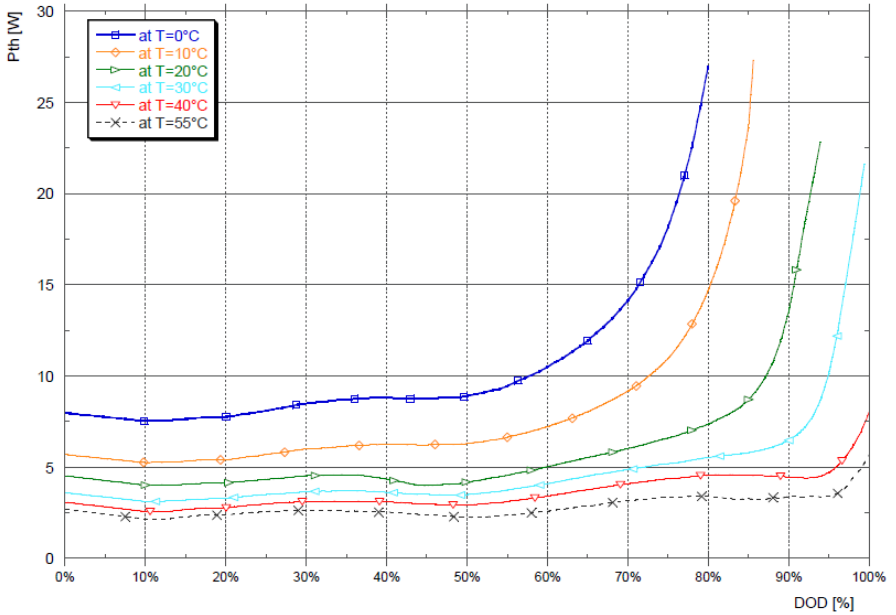
- VL51ES Li-ion cell thermo-electrical model was correlated from VL51ES thermal vacuum tests involving thermal balance and cycling ref. **S0833-16 issue1.**

VL51ES Thermal characteristics	VL51 ES Cell
$\lambda_{//}$ Thermal Conductivity (parallel to electrode) [W/m/K]	26
$\lambda_{\perp}$ Thermal Conductivity (perpendicular to electrode) [W/m/K]	2,1
C_p Thermal Inertia [J/K]	1241

VL51ES Li-ion Cell Thermal Qualification Results

Example : Thermal dissipation profile in charge at C/10 and discharge C/1.5





UN transport tests (Done on QM1 cells)

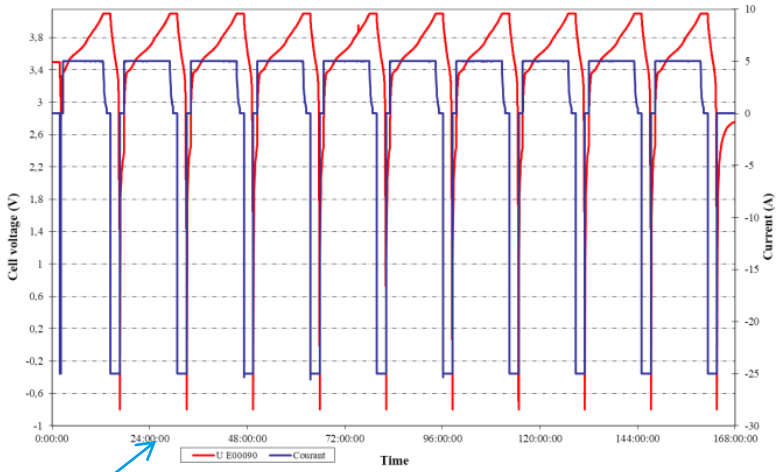
	Results	Report number
38.3.4.1 Test 1: Altitude Simulation	Passed	S2755-16
38.3.4.2 Test 2: Thermal test	Passed	S2755-16
38.3.4.3 Test 3: Vibration	Passed	S2755-16
38.3.4.4 Test 4: Shock	Passed	S2764-16
38.3.4.5 Test 5: External short circuit	Passed	S2755-16
38.3.4.6 Test 6: Impact/crush (cell test)	Passed	S2765-16
38.3.4.7 Test 7: Overcharge	Concerns rechargeable battery only	
38.3.4.8 Test 8: Force-discharge (cell test)	Passed	S2765-16

VL51ES is qualified for UN transport according ST-SG-AC10-11-Rev6

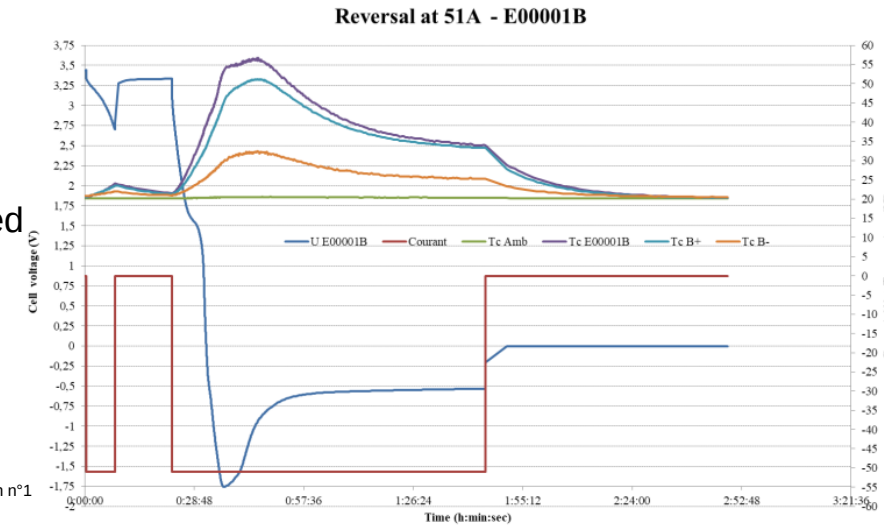
Transport UN and Safety tests

- UN Transportation tests **done successfully**

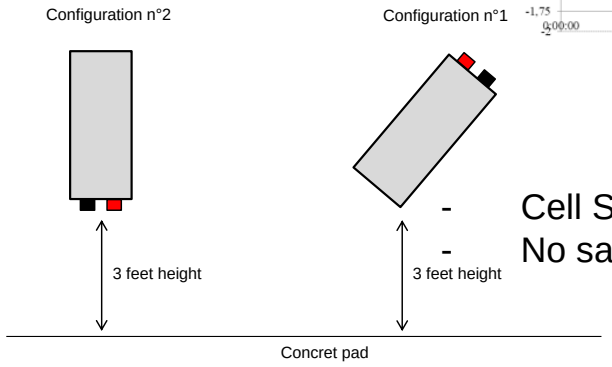
- Safety test **performed sucessfully**
  - Overcharge to 4.5 V done 10 times
  - Overdischarge down to -0.8 V done 10 times
  - Cold charge 0°C C/5
  - Full reversal
  - Drop test
  - Crush test passed successfully
  - Short circuit tests 4 to 10 mOhms



- No cell degradation
- No safety issue



- Cell Self-short formed
- No safety issue



- Cell SOC = **100%** (storage and handling SOC)
- No safety issue for the 3 tested cells

QM Life test matrix

Main parameters evaluation

LT1 (GEO): Reference accelerated life test + Impact of irradiation

LT1, LT2, & LT3 (GEO): Impact of maximum DoD

LT4 (GEO): Impact of PPS

LT5, LT6, & LT7 (LEO): Impact of maximum DoD

LT6 (LEO): Impact of irradiation

LT8 (LEO), LT6: impact EOCV

LT9 (GEO), LT12 (GEO): Impact of EOCV

LT10 (GEO): Real time cycling reference

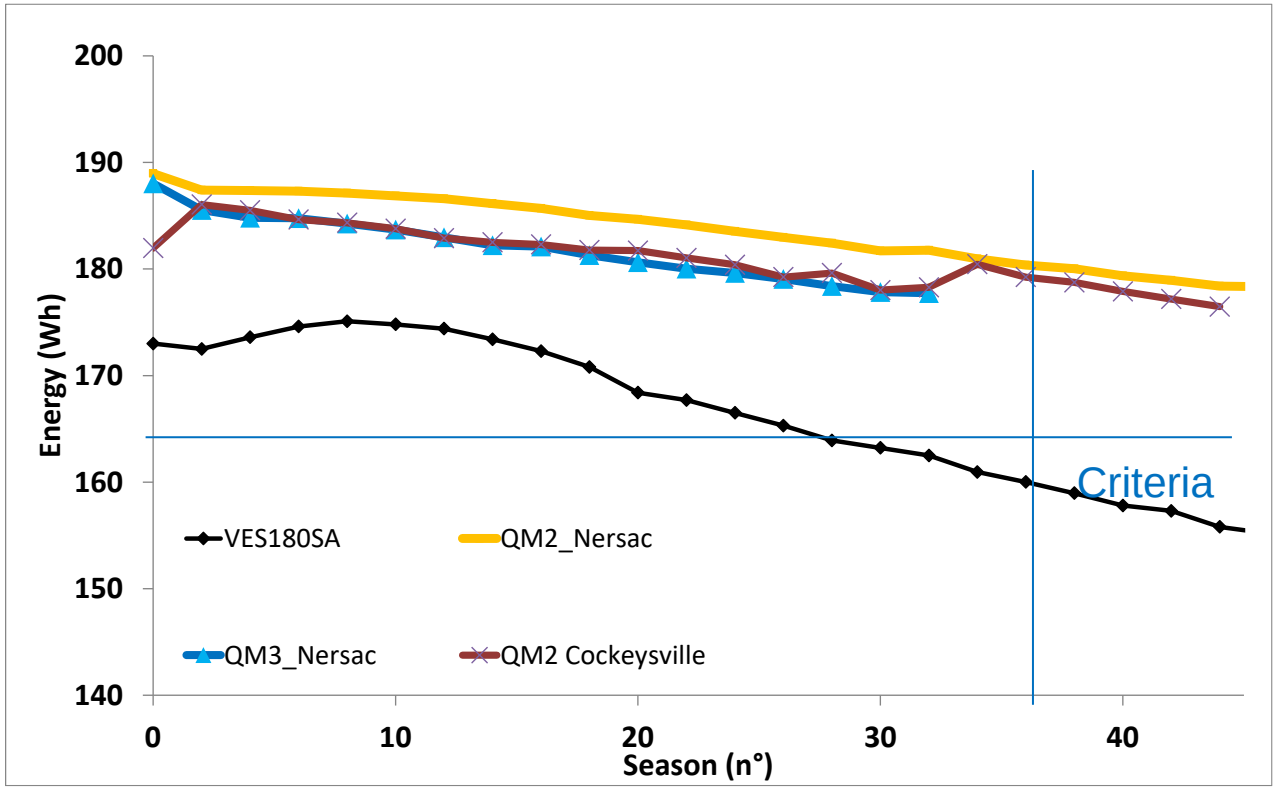
LT12, LT11 (GEO): Impact of test temperature

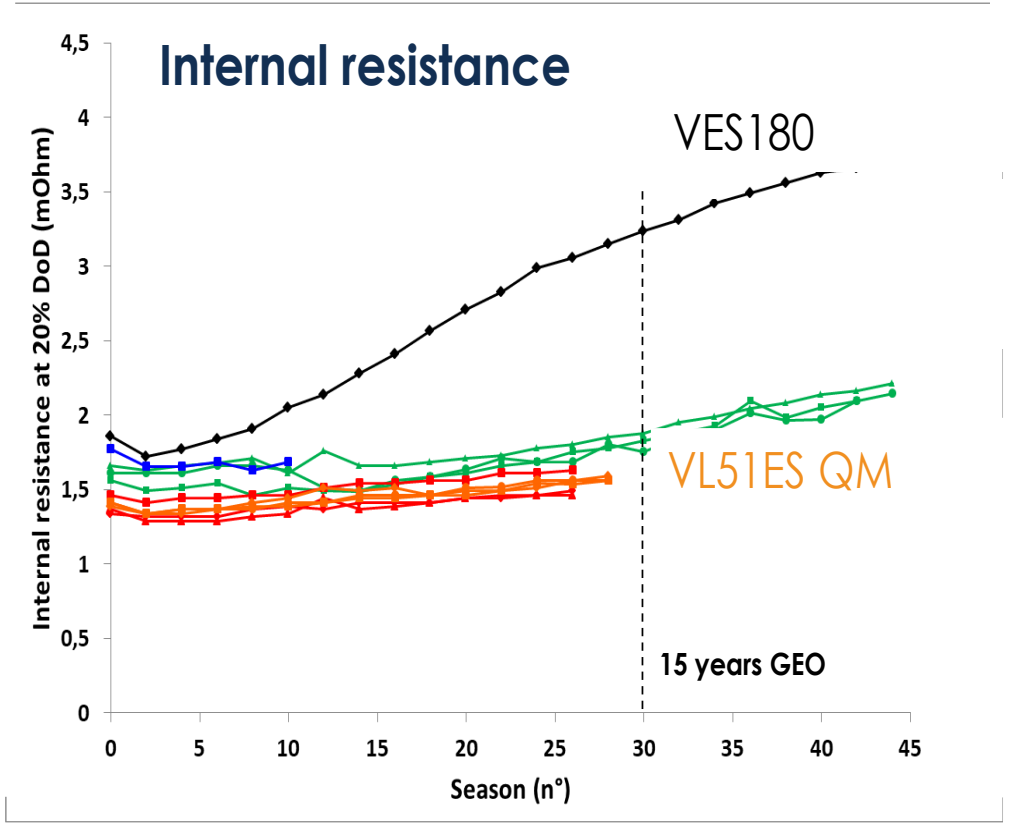
LT12: Vibration & irradiation cumulated for 1 cell

LT13: Impact of EOCV > 4.1 V (only done on QM3)

QM Life tests status

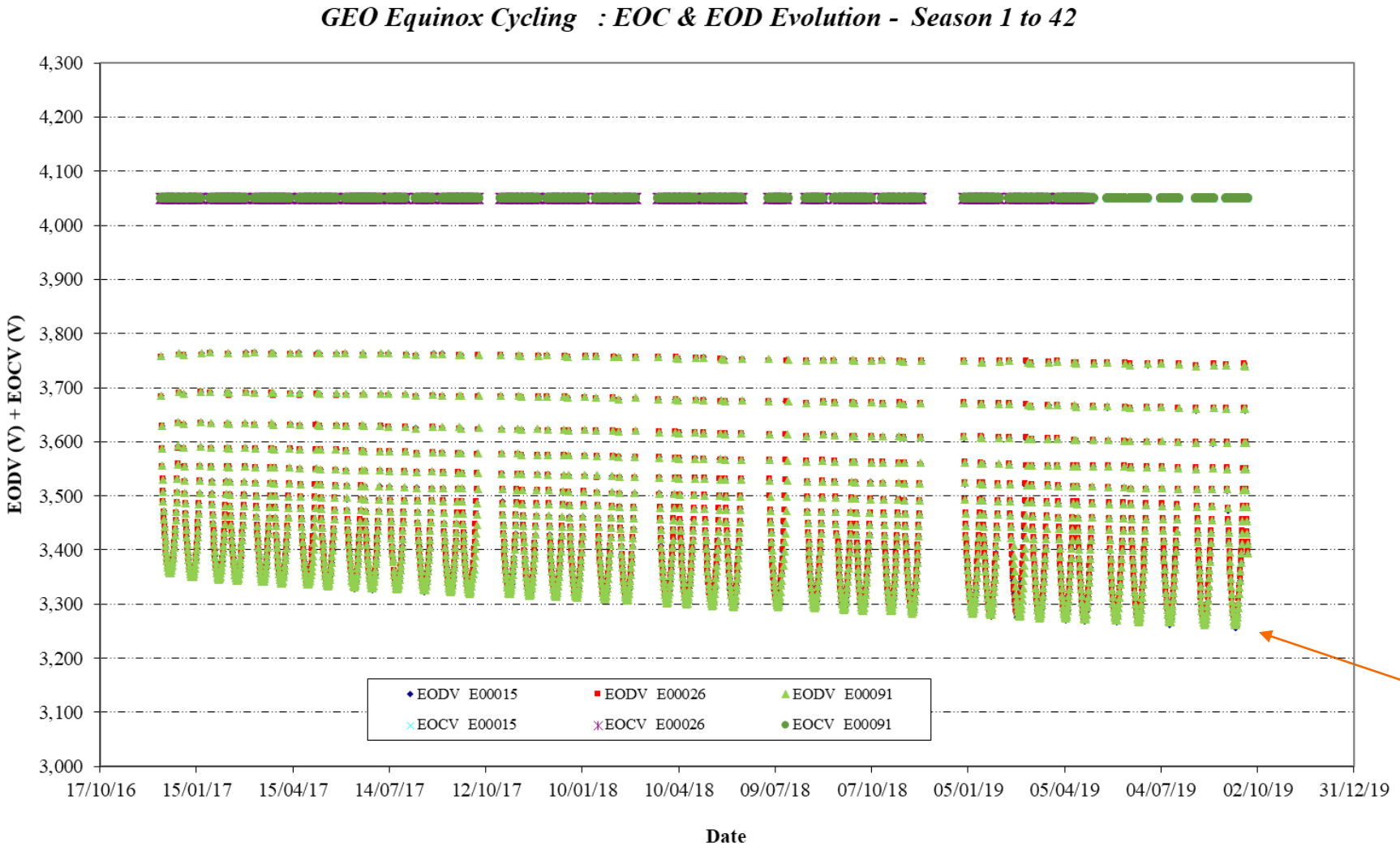
- **VL51ES reached 45 seasons** corresponding to 1.5 times 30 seasons (22.5 years) with less than 6 % energy degradation





- **Accelerated LT 80 % DOD** without solstice period, charge C/10 @ 4.05 V

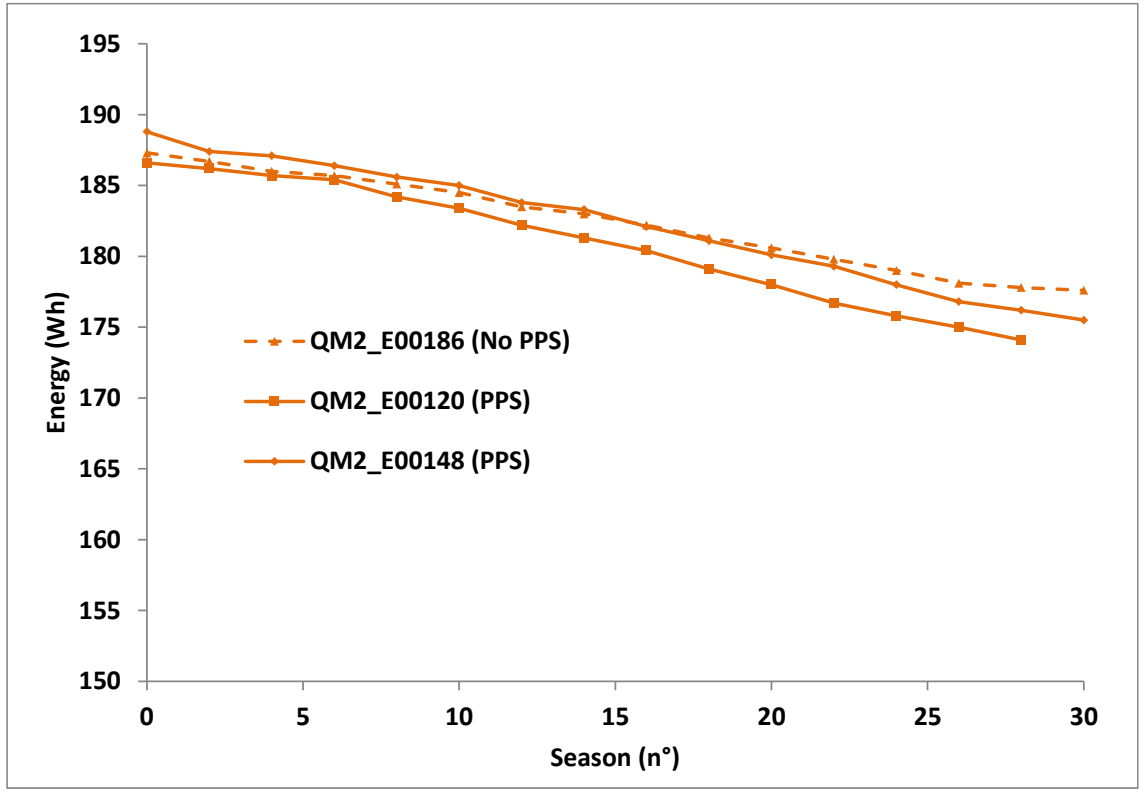
Life tests status (Acc GEO, 80% DoD, EOCV 4,05V)

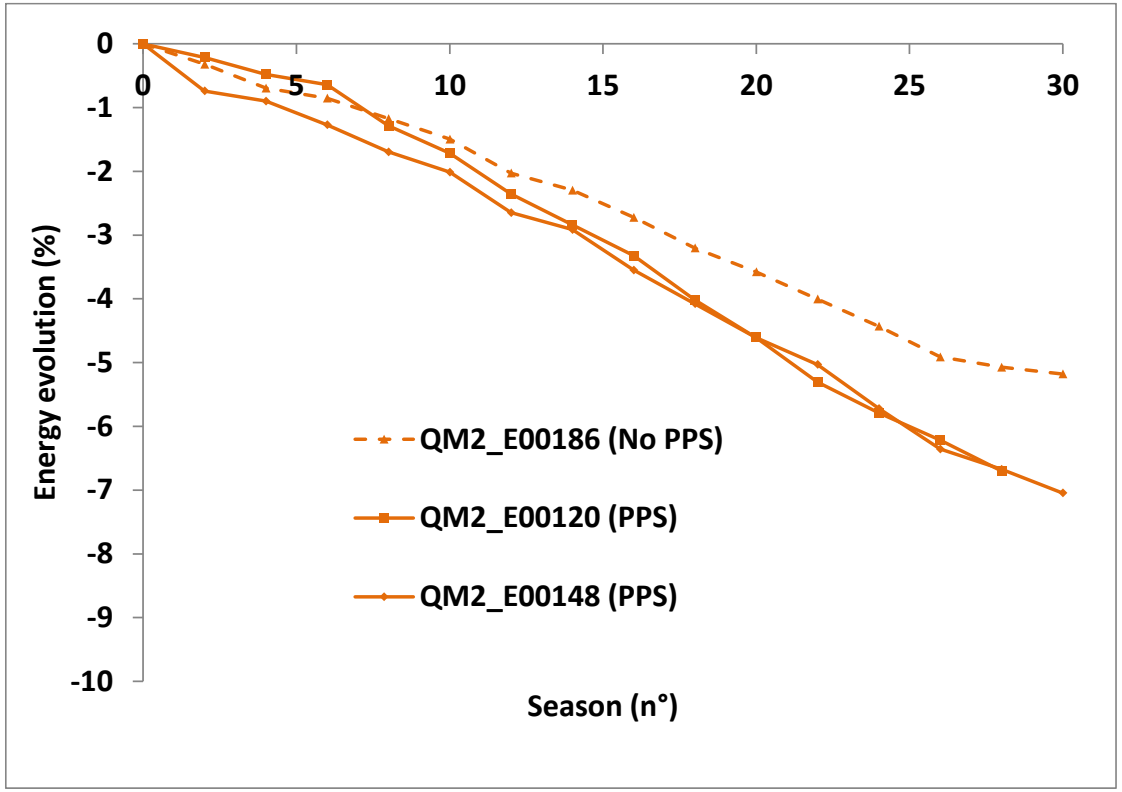


20 years !

Life tests status : Impact of Plasmic Propulsion

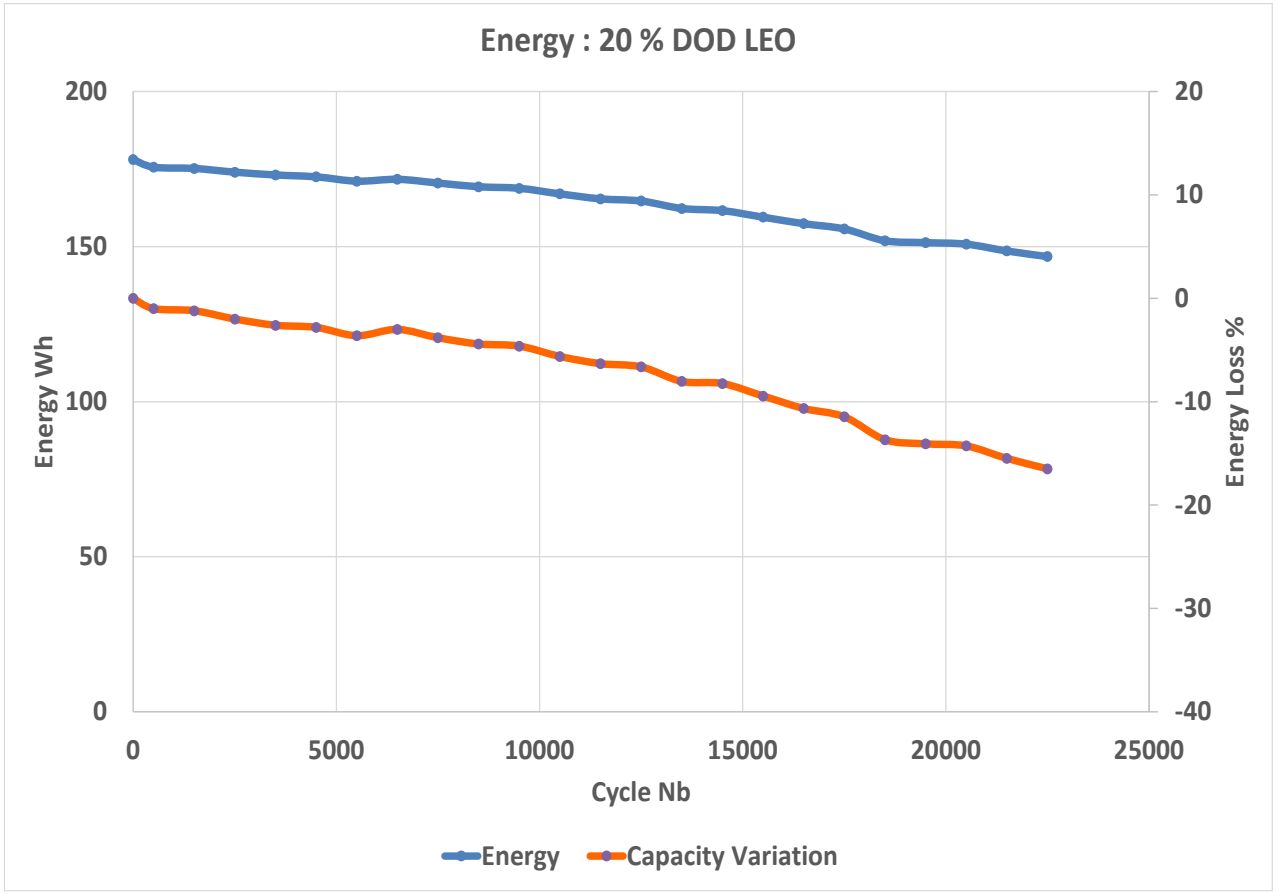
Accelerated GEO cycling with solstice & PPS (80% DoD ; EOCV = 4.075 V)

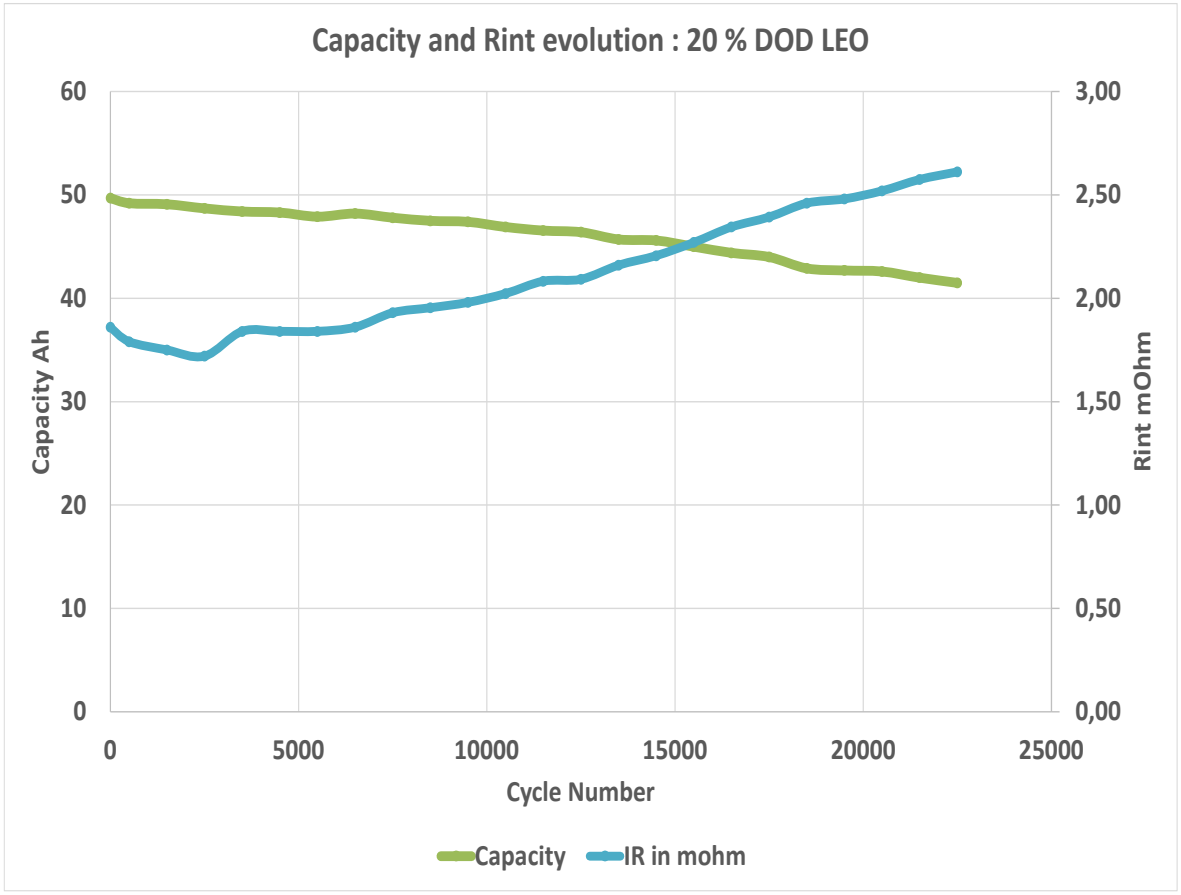




- **Full electric mission with plasmic propulsion including EOR** (2 cycles per day 20 % DOD) shows no additive degradation after 20 seasons

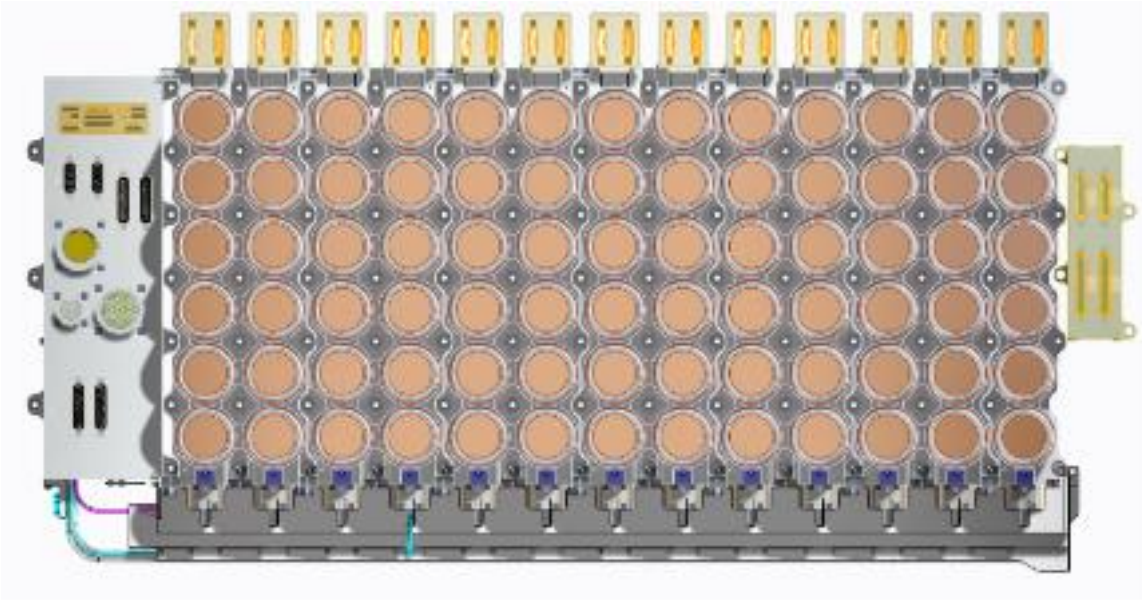
LEO performances : 20 % DOD



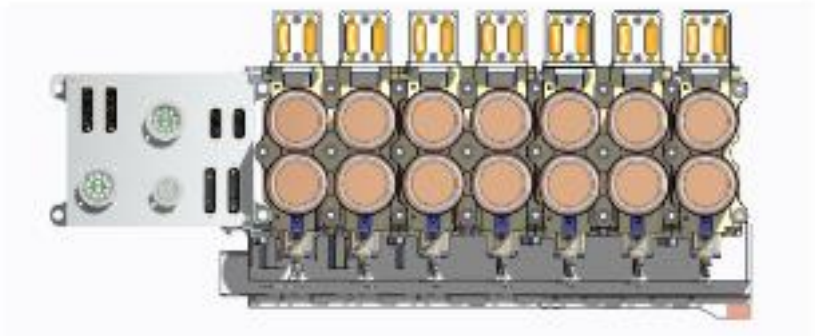


NEOSAT VL51ES Qualified Range

- **GEO/MEO** battery pack range
- Li-ion **VL51ES** based, **PS** architecture
- Option by-pass (Souriau)
- Option BMS (ASP)
- From **2P** to **6P** battery pack
- Up to 53,5V module voltage(**13S**)
- **By-pass free** from 4P
- Several Modules @ S/C level on purpose
- **Qualification Review** held in **2019**



6P13S

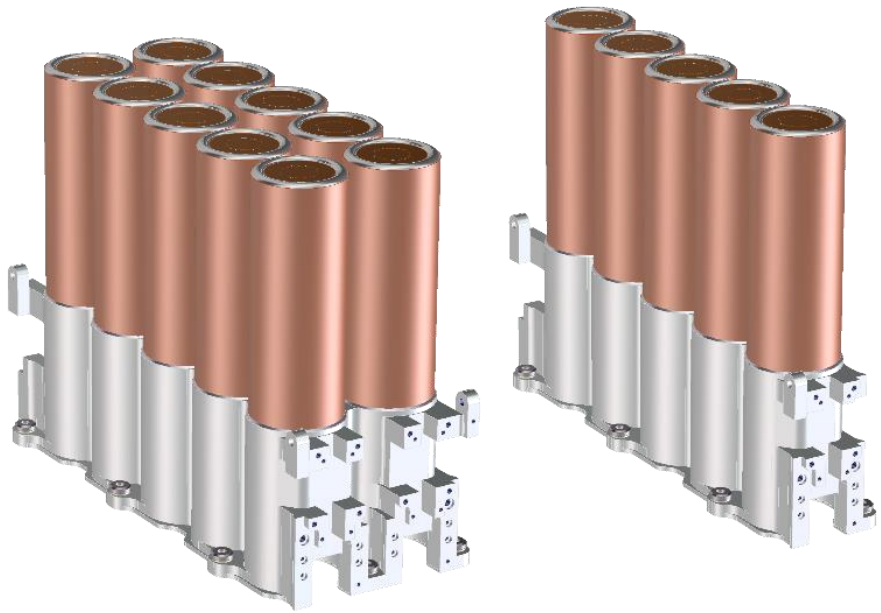


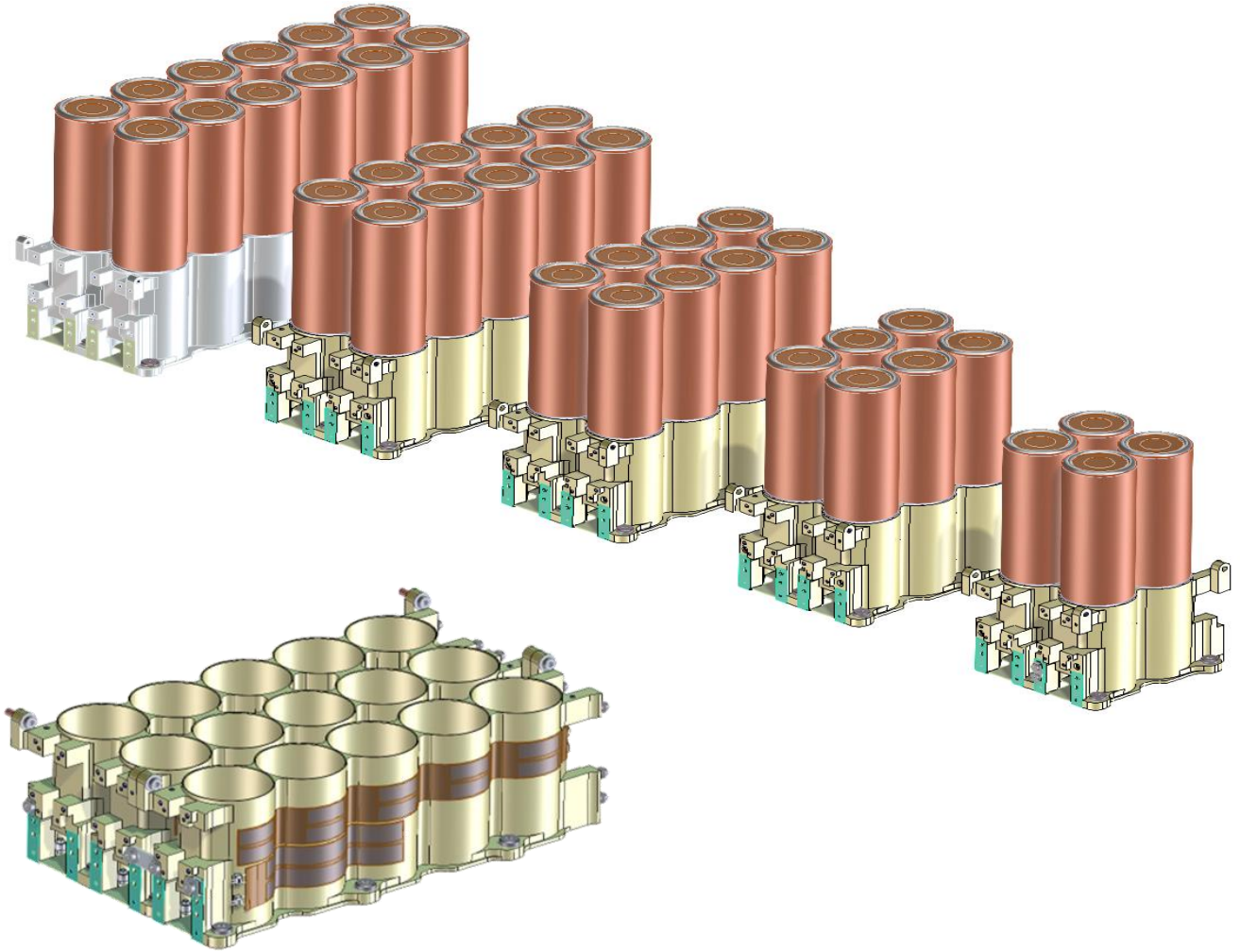
2P7S

NEOSAT VL51ES modules range

2P to **6P** cell package

Simple & **Double** cell pack



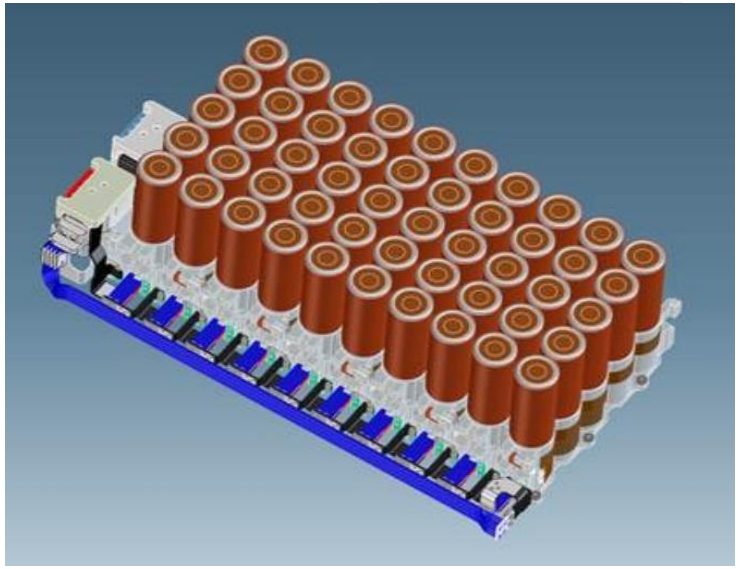


First VL51ES battery contract

Products

Four battery packs (2x5P10S and 2x5P11S) composed of:

- 10 or 11 cell packages in series made of 5 VL51ES cells in parallel
- Heaters (nominal and redundant)
- Shunt resistors
- Power busbars
- TM/TC connectors
- **No by-pass**



5P10S VL51ES battery pack (for information only)

VL51ES Qualified Range

- 14 GEO spacecraft contracted in VL51ES :
  - 5 GEO with by-pass (3P)
  - 9 GEO with and without by-pass (4P-5P)

- VL51ES Baselined on large GEO and LEO satellites:

1st Successful Launch on 9-9-2021!

VL51ES Qualified Range

Example: 5P10S **VL51ES** module versus 5P10S **VES180SA** module

	5P10S VES180SA	5P10S VL51ES	
Average **BoL Energy**	8550 Wh	9100 Wh	↗ ≈ **6.5 %**
Average **Weight**	74,5 Kg	72,2 Kg	↘ ≈ **3 %**
Average **Energy Density**			↗ ≈ **10 %** *
Interface (LxWxH)	810 x 440 x **269** mm	810 x 440 x **249** mm	
Internal Resistance	≈ 5 mΩ (20°C, 60%)	≈ 4 mΩ (20°C, 60%)	↘ ≈ **20 %**
Same Fit and Function battery (footprint, interface, thermal control, BMS…)			

** Becomes **17%** w/o by-pass (67,9kg), and becomes **19%** in LCP configuration (66,7kg)*

Disclaimer and copyright reservation

Definition - TotalEnergies / Company
The entities in which TotalEnergies SE directly or indirectly holds an interest are separate and independent legal entities. The terms "TotalEnergies", "TotalEnergies company" and "Company" used in this document are used to refer to TotalEnergies SE and its affiliates included in the scope of consolidation. Similarly, the terms "we", "us", "our" may also be used to refer to these entities or their employees. It cannot be inferred from the use of these expressions that TotalEnergies SE or any of its affiliates is involved in the business or management of any other company of the TotalEnergies company.

Disclaimer
This presentation may include forward-looking statement within the meaning of the Private Securities Litigation Reform Act of 1995 with respect to the financial condition, results of operations, business, strategy and plans of TotalEnergies that are subject to risk factors and uncertainties caused by changes in, without limitation, technological development and innovation, supply sources, legal framework, market conditions, political or economic events.
TotalEnergies does not assume any obligation to update publicly any forward-looking statement, whether as a result of new information, future events or otherwise. Further information on factors which could affect the company's financial results is provided in documents filed by TotalEnergies with the French *Autorité des Marchés Financiers* and the US Securities and Exchange Commission.
Accordingly, no reliance may be placed on the accuracy or correctness of any such statements.

Copyright