

“Advances In Battery Technology Relevant For Planetary Probes”



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- First rechargeable Lithium-ion batteries powering spacecraft in orbit around Earth, Mars and Venus ✓
- 19 spacecraft launched powered by ABSL Lithium-ion ✓
 - 9 LEO (including longest serving Li-ion battery 4.5years)
 - 5 Interplanetary
 - 4 Geostationary Transfer Orbit
 - 1 Medium Earth Orbit
- Awarded battery contracts for Lithium-ion 60+ spacecraft and launch vehicles ✓
- More than 2,500 Lithium-ion cell years in space without failure ✓

✓ denotes industry leader

- 1945 Government agency: UKAEA
- 1996 Public company: AEA Technology plc
- 2005 Purchased by US Company
- 2005 Renamed as ABSL Power Solutions Ltd (space unit: ABSL Space Products)
- 2006 ABSL Inc. registered and operating as a US Small Business

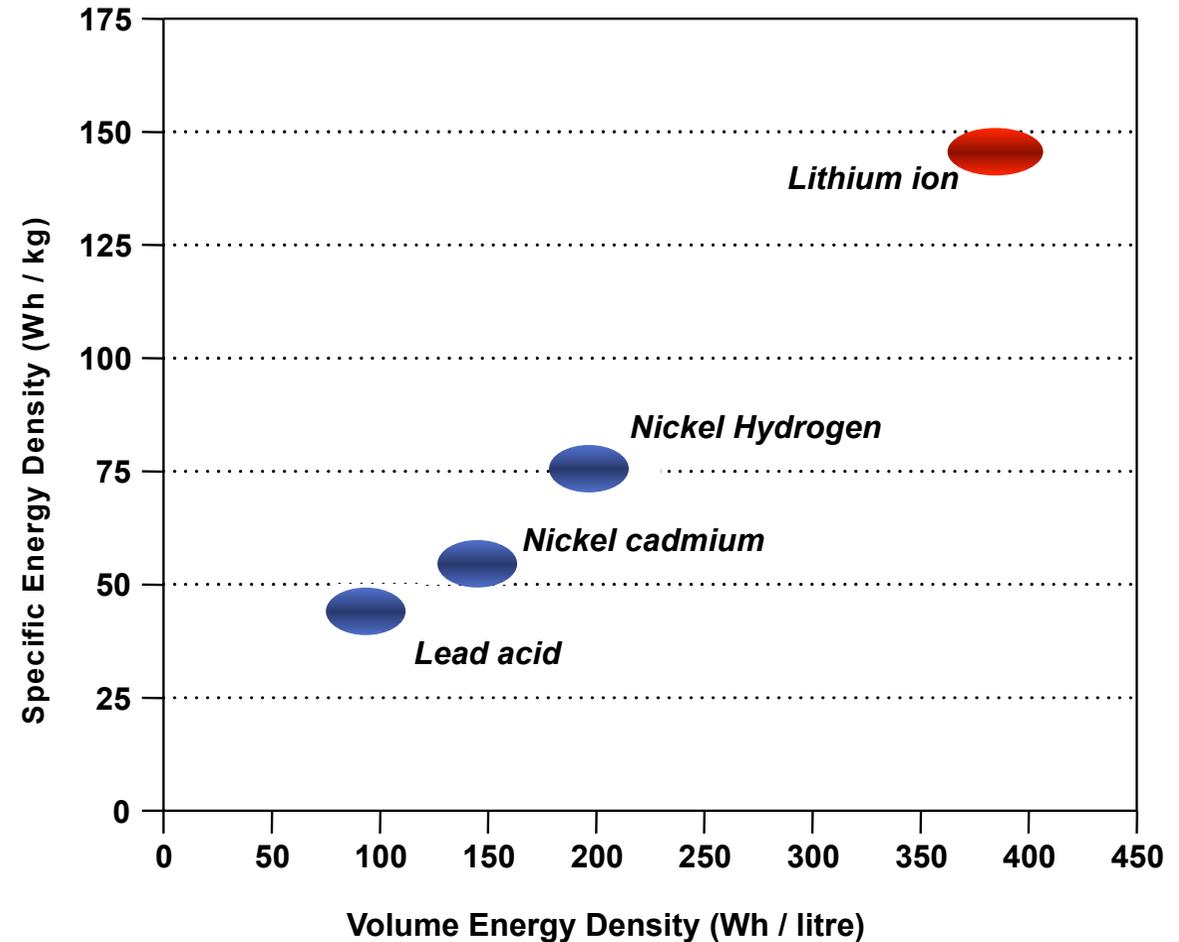
Batteries For All Space Mission Types

- LEO
 - AEOLUS
 - ARGO
 - CASSIOPE
 - CFESat
 - Cryosat
 - Demeter
 - DSE
 - ESSAIM
 - **FOTON ***
 - GOCE
 - Microscope
 - Nsat
 - Oryx
 - Parasol
- GEO
 - Picard
 - Pleiades
 - PROBA
 - Rapideye
 - SAR Lupe
 - Saudisat
 - Spirale
 - SSR-1
 - TACSAT-3
 - TALISAT
 - TerraSAR-X
 - THEOS
 - ZASat-1
- GTO
 - GSAT-4
 - SDO
 - ST5
 - STRV1-c
- HEO
 - THEMIS
- MEO
 - GSTB-V2/A
- Interplanetary
 - **Beagle2**
 - Kepler
 - Mars Express
 - **Philae**
 - Rosetta
 - Venus Express
 - LRO
- Lagrange
 - Herschel
 - Planck
- Launch Vehicles
 - AHPS
 - KSLV-1

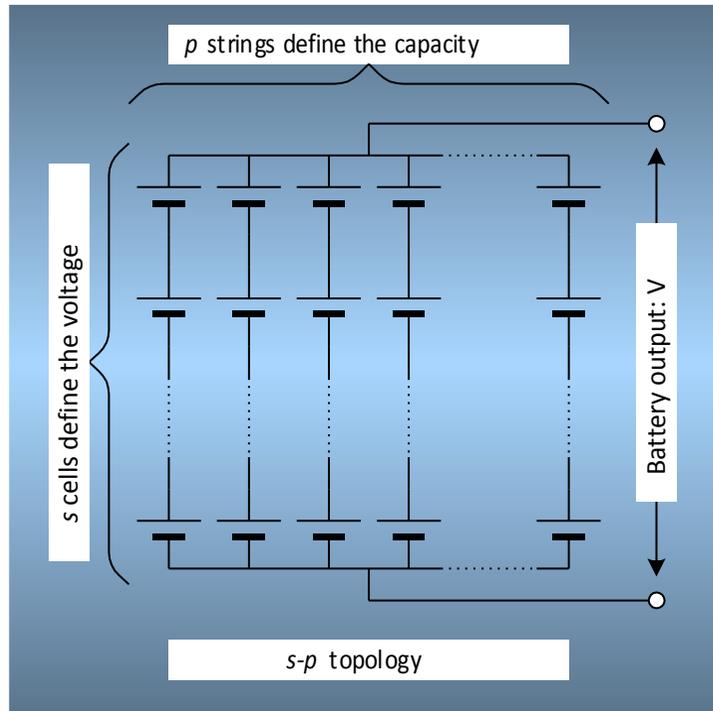
* Plus re-entry

Lithium-ion Benefits

- Low mass
- Small Footprint
- Low Maintenance
- Simple integration



ABSL Small-Cell Approach



- ABSL uses commercially available cells
- ABSL performs one-off space qualification programs
- ABSL procures large batches of cells
 - Lot Acceptance test on each batch
 - Each cell individually screened
 - Cells are matched for flight batteries
 - Extremely high cell uniformity ensured
- ABSL connects cells in s-p topology
 - Fine tune capacity, voltage
 - Internal protection devices replace bypass
 - SPF results in small capacity loss
 - No charge balancing required



Philae Lander Battery

- Rosetta/Philae launched March 2004
- 10.5 year cruise phase
- Orbit around comet 67P Churyumov-Gerasimenko
- Philae lander and Rosetta powered by ABSL Li-ion

Courtesy ESA



Courtesy ESA

Philae Lander Battery

- 14 ABSL 18650HC cells
- Two batteries delivered
 - 25.5V, 3Ah
 - 7V, 10.5Ah
- Rosetta 50Ah battery
- Staggered cells to minimize footprint
- Battery performing nominally



Parameter	2s7p	7s2p
Max Voltage	8.4	29.4
Min Voltage	5.0	17.5
Capacity (Ah)	10.5	3.0
Mass (kg)	0.72	0.72
Height (mm)	71	71
Footprint (mm)	118.5	63.2

Beagle 2 Lander

- Mars Express launched June 2003
- Carried Beagle 2 Mars lander
- 6 month Cruise phase to Mars
- Mars Express 2.5 yrs Martian Orbit (5-55%DOD)
- Beagle 2 lost post deployment, Christmas 2003
- Beagle 2 battery health confirmed via health check



Beagle 2 Battery

- Highly customized design
 - Small-cells make max use of odd footprint
 - Battery structure part of spacecraft structure
- Low temperature
 - Li-ion self-heating utilized to warm battery in Martian night (-30degC)

Parameter	6s9p
Max Voltage	25.2
Min Voltage	15.0
Capacity (Ah)	13.5
Mass (kg)	2.6
Height (mm)	66 (107 pillars)
Footprint (mm)	266x138 max



Next-Generation Li-ion

- ABSL has space qualified three Lithium-ion 18650 cells
 - Two high density (110 and 150Wh/kg at battery level)
 - High rate (10C continuous capability, >80C pulse capability)
- Cells in pre-qual
 - Low temp (80% capacity @ -40degC)
 - 180Wh/kg battery level
- Mature, scalable packaging scheme

28V, 78Ah

270V, 2.2Ah



28V, 1.5Ah

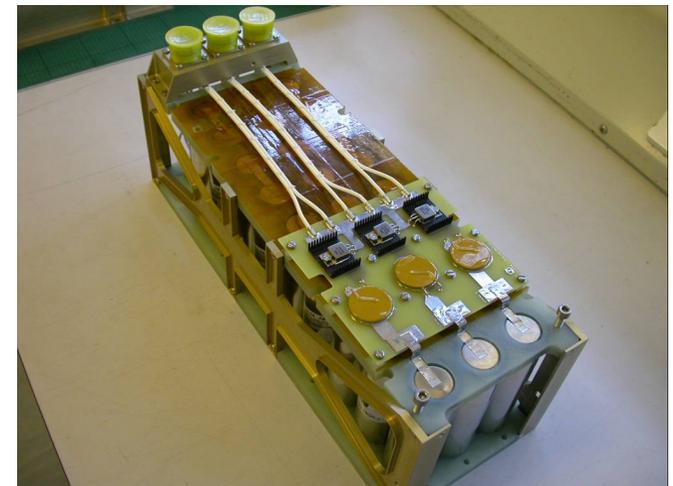
28V, 15Ah

- Two week LEO science experiment
- Prior to re-entry, spacecraft switched onto primary battery
- Powers re-entry operations and 10-12 hours recovery period
- Driver for battery, high energy density and low temp performance



ABSL 3311PR Cell

- High Energy Density Lithium Primary
 - >370Wh/kg at -10degC
 - >480Wh/kg at 20degC
 - >500Wh/kg at 60degC
- Mechanically highly robust
 - Shock 90g for 40ms
- 9s3p Batteries in build
 - 90Ah
 - Over current, charge protection
 - Qualification imminent



Acknowledgements

- ABSL would like to thank our friends and colleagues in the space industry for their continued support of our space battery program





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