The Use of Small Cell Lithium-Ion Batteries for Small Satellite Applications

Chris Pearson, Carl Thwaite, Nick Russel

AEA Technology
Contents

- Space Batteries: Why?
- Current state of the art: Lithium-ion
- Parallel Approaches: Large cell & Small cell
- Small Cell Benefits
- Design Maturity
- Example Smallsat Hardware
- Programme Milestones
Space Batteries

- Continual load demand
- Nominal array power
  - Periodic shadowing
  - Pulse
  - LEOP
  - Safe modes

LEO
- 16 orbits/day
- 5500 cycles/yr
Spacecraft Battery Selection Factors

- Energy Density
  - Max payload
  - Min footprint
- Cost
- Reliability
  - Mission critical
- Complexity
  - Operation
  - Charge control
  - Protection
  - Maintenance
  - Instrumentation

© 2004 AEA Technology plc
Lithium-ion Battery Features

- Low mass
- Small Footprint
Lithium-ion Battery Features

- Low mass
- Small Footprint
- Simple Charge Algorithm
  - Voltage only
  - No trickle
Lithium-ion Battery Features

- Low mass
- Small Footprint
- Simple Charge Algorithm
- Low Maintenance
  - No reconditioning
  - Easy storage
  - Orientation tolerant
Lithium-ion Battery Features

- Low mass
- Small Footprint
- Simple Charge Algorithm
- Low Maintenance
- Space Proven
Parallel Approaches: Large Cell

- ‘One off’ cell designs
  - Qualification cost
  - Oversized batteries
  - SPF, large capacity loss
  - Bypass required
  - Electronics cost, complexity
  - Bypass
  - Charge balance
Parallel Approaches: Small Cell

- Standard 18650 commercial cells
- One-off space qualification
- Ensure continued uniformity
  - LAT Batches
  - Individually screen
  - Match for flight
- SPF small capacity loss
- No charge balancing required
- Protection at cell level
Small Cell Approach: Benefits

- Highly scalable
- Standardised packaging
- Optimise capacity
- Extra string(s) for margin
- Accommodate mission creep

Battery Energy Density (Wh/kg) vs Battery Mass (kg) for various satellites:

- ST5
- SSTM
- RoLand
- RoLand II
- PROBA
- Oryx
- Beagle2
- Microsat
- ESSAIM
- GSFC EQM
- Herschel-Plank
- Rosetta
- Venus Express
- Mars-Express
- IAI MBT
- SSR1
- Cryosat
- GSTB-V2
- GOCE
- Aeolus
- TerraSAR-X
Small Cell Approach: Benefits

- Highly scalable
- Predictable performance
  - Life test programme (Storage, LEO, GEO…)
  - BEAST
  - Proven by IOT
Small Cell Approach: Benefits

- Highly Scalable
- Predictable Performance
- Low complexity
  - No electronics
Small Cell Approach: Benefits

- Highly Scalable
- Predictable Performance
- Low complexity
- Multi-decking
  - Footprint
Small Cell Approach: Benefits

- Highly Scalable
- Predictable Performance
- Low complexity
- Multi-decking
- Modular batteries
  - Capacity flexibility
  - Low-cost flight spares
  - Mass balance
  - Distributed volume
Mature Design

- Low-risk programme
  - Established heritage
  - High production potential
  - Chemistry switch
- Many qualified designs
  - BTP programmes
  - Small design tweak: PFM
  - “Cell Array” versatility

<table>
<thead>
<tr>
<th>Cell Array</th>
<th>Module Mass (kg)</th>
<th>Number Of decks</th>
</tr>
</thead>
<tbody>
<tr>
<td>4x2</td>
<td>0.4</td>
<td>3</td>
</tr>
<tr>
<td>6x2</td>
<td>0.6</td>
<td>1</td>
</tr>
<tr>
<td>7x2</td>
<td>0.7</td>
<td>1</td>
</tr>
<tr>
<td>6x6</td>
<td>1.9</td>
<td>1</td>
</tr>
<tr>
<td>6x4</td>
<td>2.4</td>
<td>1</td>
</tr>
<tr>
<td>6x9</td>
<td>2.6</td>
<td>1</td>
</tr>
<tr>
<td>6x11</td>
<td>3.3</td>
<td>1</td>
</tr>
<tr>
<td>8x10</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>6x16</td>
<td>4.7</td>
<td>1</td>
</tr>
<tr>
<td>10x30</td>
<td>5.3</td>
<td>1</td>
</tr>
<tr>
<td>8x16</td>
<td>6.6</td>
<td>1</td>
</tr>
<tr>
<td>6x24</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>10x28</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>12x24</td>
<td>14.4</td>
<td>2</td>
</tr>
<tr>
<td>8x44</td>
<td>16.8</td>
<td>2</td>
</tr>
<tr>
<td>8x52</td>
<td>25.4</td>
<td>1</td>
</tr>
</tbody>
</table>
Example SmallSat Battery Hardware

RoLand
Nom 24.5V
6Ah
0.7kg

PROBA
Nom 24.5V
6Ah
1.9kg

SaudiSat - 2
Nom 14V
3Ah
2.4kg

ORYX
Nom 21V
6Ah
0.4kg

MICROSAT
Nom 28V
15Ah
4.0kg

Beagle 2
Nom 24.5V
6Ah
1.4kg
AEA Space Battery Milestones

1990s: R&D, Lifetest, funding
2000: First AEA battery launched: STRV-1c
2001: PROBA launched with first ESA Lion battery
2003: PROBA mission extended for 2nd time
2003: Mars Express/Beagle launched – 1st I/P Lion
2003: First GEO battery contract
2004: Rosetta/Philae Launched
2004: First flight battery contract from US prime
2004: Under Contract for 30+ space programmes
2004: Selected to develop Space Shuttle AHPS Battery
2004: SaudiSat-2/Microsat Launched