Designing Power Systems for Mission Success

William Sear, Lucas Reed, and Xiaohan “Henry” Shi
Overview

• PolarCube Satellite Mission
• Electrical Power System (EPS) Configuration
• PolarCube Satellite Requirements
  • EPS Converter Stability
  • Subsystem Power Draws
• PolarCube Power Budget
  • Previous Models
  • EPS Concerns
  • New Approaches
PolarCube Mission Statement

PolarCube will perform tropospheric temperature sounding using the 118.7503 GHz O₂ resonance, by using a radiometer.

Ice layer average of past 30 years

Present Day
PolarCube Electrical Subsystems

- Electrical Power System (EPS)
- Attitude Determination and Control (ADCS)
- Command and Data Handling (CDH)
- Communications System (COM)
- Payload Radiometer (RAD)
We are the power outlet in Space!
Electrical Power System Design

We are the power outlet in Space!

3.3 Volt Regulated and Protected Line
12 Volt Regulated and Protected Line
Battery Voltage (7.4-8.4 Volt) Protected Line
Electrical Power System Design

Four Critical Systems:

- Solar Cells
- Maximum Peak Power Trackers
- Batteries and Battery Manager
- Voltage Regulators
Electrical Power System Design

Four Critical Systems:
Electrical Power System Design

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Electrical Power System Design

Four Critical Systems:

- Maximum Power Point Tracking
- Solar Panels
- Batteries
- Main Power Control
EPS Converter Stability

3.3 Volt Buck Converter  
12 Volt Boost Converter
## Sub-System Power Draws

<table>
<thead>
<tr>
<th>Satellite Modes</th>
<th>Safe Mode</th>
<th>COM Transmit</th>
<th>Active Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXX</td>
<td>2.23 W</td>
<td>2.23 W</td>
<td>2.23 W</td>
</tr>
<tr>
<td>CDH</td>
<td>0.98 W</td>
<td>0.75 W</td>
<td>0.75 W</td>
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<tr>
<td>EPS</td>
<td>4.13 W</td>
<td>4.13 W</td>
<td>4.13 W</td>
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<tr>
<td>ADCS</td>
<td>1.78 W</td>
<td>9.78 W</td>
<td>1.78 W</td>
</tr>
<tr>
<td>COM</td>
<td>0.3 W</td>
<td>0.3 W</td>
<td>12.2 W</td>
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</table>
# Old Power Budgets

Reference UH5-SYS114.2 for format and calculations

## Assumptions

<table>
<thead>
<tr>
<th>Period</th>
<th>Orbit period</th>
<th>Sunlit period</th>
<th>Eclipse period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>93 min</td>
<td>56 min</td>
<td>37 min</td>
</tr>
<tr>
<td>Battery voltage</td>
<td>7.40 V</td>
<td>10.40 AH</td>
<td>76.95 WH</td>
</tr>
<tr>
<td>Estimated panel output</td>
<td>14.00 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPS PV efficiency</td>
<td>93%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Max DOD allowed: 25%
Charge / discharge ratio: 1.25

## Spacecraft Modes

### Consumption per Orbit

<table>
<thead>
<tr>
<th>Power per mode</th>
<th>Charging</th>
<th>Safe</th>
<th>BusPriority</th>
<th>COM Priority</th>
<th>Payload Priority</th>
<th>Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.790 mW</td>
<td>7.790 mW</td>
<td>7.790 mW</td>
<td>13.340 mW</td>
<td>16.870 mW</td>
<td>27.140 mW</td>
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</table>

Power consumed during sunlit duration
Power consumed during eclipse duration

### Required Storage per Orbit

<table>
<thead>
<tr>
<th>Battery needs to discharge</th>
<th>4.80 WH</th>
<th>4.80 WH</th>
<th>4.80 WH</th>
<th>8.23 WH</th>
<th>10.40 WH</th>
<th>16.74 WH</th>
<th>2.57 WH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery needs to store</td>
<td>6.00 WH</td>
<td>6.00 WH</td>
<td>6.00 WH</td>
<td>10.28 WH</td>
<td>13.00 WH</td>
<td>20.92 WH</td>
<td>3.59 WH</td>
</tr>
</tbody>
</table>

Power discharged from battery during eclipse
Efficiency of battery charging - in vs. out
Power needed to charge battery during sunlit

<table>
<thead>
<tr>
<th>Battery voltage</th>
<th>7.4 V</th>
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<th>7.4 V</th>
<th>7.4 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>76.96 WH</td>
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<td></td>
</tr>
</tbody>
</table>

Watt-hours into bus (sun)
Amp-hours into bus (sun)
Amps into bus (sun)
EPS Battery Stability

Battery Charging Curve

Battery Discharging Curve
Solar Panels

![Graph showing the relationship between voltage and current for solar panels. The x-axis represents voltage (V) ranging from 0 to 3, and the y-axis represents current (mA/cm²) ranging from 0 to 18. The graph shows a linear decrease in current as voltage increases, with a sharp drop near 2.5 V.]
Maximum Peak Power Trackers

- Main component is a 4 switch buck-boost converter
- Allows for more power over a wider range of inputs than Direct Energy Transfer
  - Each string will connect to MPPT converter through a diode
    - This will keep the cells with the most power as close to MPPT as possible
  - Output tied to power bus
- Panel voltage controlled by manipulating duty cycle

Characteristic Curves for Ideal Power Tracking
Systems Toolkit Modeling
Instantaneous Power

Instantaneous Power w/One Wing & 8 UTJ

[Graph showing a periodic pattern of power gain/loss over orbit number]
Battery State of Charge
Future Work

• Integrate EPS Model with ADCS Pointing and Control Algorithm
• Optimize Power Profile to minimize Ram Vector Surface Area of Satellite
• Work to better model degradation of all systems and components
• Finalize Sub-System Power Draw Figures
• Optimize Solar Panels and Maximum Peak Power Point Trackers