Ultralight photovoltaic power and fuel tanks

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• Ultralight modular integrated photovoltaics mass and size
  – Module level description
  – Ultralight photovoltaic specific power on Mars

• Fuel and tank mass and size
Large Scale Space Solar Power: Specific Power

Current State of Art

• Off-the-shelf PV and power components

Ultralight Approach

• Innovate to develop science and technology for a lightweight, high-performance modular system; assume current launch costs

<table>
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<tr>
<th>SPS</th>
<th>USEF</th>
<th>JAXA</th>
<th>ESA</th>
<th>Alpha</th>
<th>Caltech</th>
</tr>
</thead>
<tbody>
<tr>
<td>W/kg</td>
<td>41</td>
<td>98</td>
<td>132</td>
<td>33</td>
<td>2000-6000</td>
</tr>
<tr>
<td>Max size for deployment</td>
<td>100 m x 95 m</td>
<td>3.5 km</td>
<td>15 km</td>
<td>6 km</td>
<td>60 m x 60 m</td>
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Watts on ground/kg in space

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Module Design Summary

60 m x 60 m square architecture. Designed for tile rotation <1° under SRP.

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>369</td>
</tr>
<tr>
<td>Tiles (@80 g/m²)</td>
<td>288</td>
</tr>
<tr>
<td>Strip structure</td>
<td>19</td>
</tr>
<tr>
<td>Hub</td>
<td>50</td>
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<tr>
<td>Booms</td>
<td>12</td>
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</table>

Booms:
4 × coilable CFRP trusses
42 m long, ~1.5 kg each, ATK

Strips:
1.5 m wide
20 per quadrant
CFRP TRAC longerons (2 x 64 µm thick tape springs, max stowed strain < 0.5%)

Stowed module:
1.5 m height
0.926 m diameter

Min. bend radius: 14 mm
Module Power on Mars

Space: 4.7 MW at AM0 (1330 W/m²)

Daily average on Mars, no dust: = 529 kW
(147 W/m², from Dave)

Daily average on Mars, dust storm: 118 kW =
(33 W/m², from Dave)

Module weight = 370 kg

Specific power on Mars:

529/370 = 1.4 kW/kg (no dust)

118/370 = 318 W/kg
Weight of fuel tanks

- Data derived from rocket motor tank specs
- Tank wall thickness:
  - Falcon 9 Heavy: 4.7mm (reusability)
  - Space Shuttle external tank and Atlas rocket (‘old school’): 2.5 to 10 mm
  - Centaur upper stage: 0.36 to 0.41 mm
  - Saturn V first stage: 4.32 to 6.45 mm
- Tank volume and size:
  - Saturn V:
    - 43 m tall and 10 m diameter
    - 770,000 liters of kerosene and 1.2 million liters of liquid oxygen
- Tank and fuel weight (Saturn V):
  - (314 m2 x 0.003 m = 0.94 m3) x 2830 kg/m3 = 2600 kg 2.6 metric tons
  - 770,000 liters of kerosene and 1.2 million liters of liquid oxygen: Assume it’s all oxygen (1.97 million liters of liquid oxygen)x(1.14 kg/l) = 2.25 million kg = 2,250 metric tons of liquid oxygen