Heliogyro-Configured Solar Sail Spacecraft

Peerawan Wiwattananon, National Institute of Aerospace, (in Residence at NASA Langley Research Center, USA)

Peerawan.Wiwattananon@nasa.gov

Robert G. Bryant, NASA Langley Research Center, USA
Solar Photons - Solar Sail Missions

Heliophysics Missions

Solar sails are not only able to balance at $L_1$, $L_2$, ..., $L_5$ points but they are station-keeping at other regions in space without using fuel on board.

- De-orbit end of life satellites
- Asteroid Mapping
- Asteroid Redirect
- Near Earth Object Monitoring

Background Image Credit: NASA [http://www.nasa.gov/centers/marshall/images/content/112448main_solar_sail_sun_earth_frame0016_4000x3000.jpg](http://www.nasa.gov/centers/marshall/images/content/112448main_solar_sail_sun_earth_frame0016_4000x3000.jpg)
2-Bladed Heliogyro Solar Sail

Large Solar Sail Area (~ 720 m²)

Deploy: Centrifugal Force + Motor Assist

Anti-Jamming Technology

Solar Sail: 2 μm thick

Three ways to steer the solar sail
1. Rotate the whole spacecraft
2. Tilt the blades to change angle of solar pressure
3. Retract/extend the blades to change CP relative to CM

Retractable solar sail system: control CM/CP*, avoid thermal heat flux

CM = center of mass, CP = center of pressure

<table>
<thead>
<tr>
<th>Heliogyro</th>
<th>Characteristic Acceleration [mm/s²]</th>
<th>Sail Loading [g/m²]</th>
<th>% of payload units to the whole spacecraft units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18U-4B(a)</td>
<td>0.85</td>
<td>9.68</td>
<td>33</td>
</tr>
<tr>
<td>18U-8B(a)</td>
<td>0.73</td>
<td>11.25</td>
<td>28</td>
</tr>
<tr>
<td>24U-4B(a)</td>
<td>0.75</td>
<td>10.94</td>
<td>41</td>
</tr>
<tr>
<td>24U-4B(b)</td>
<td>0.62</td>
<td>13.30</td>
<td>59</td>
</tr>
<tr>
<td>24U-4B(c)</td>
<td>0.64</td>
<td>12.90</td>
<td>50</td>
</tr>
<tr>
<td>30U-4B(a)</td>
<td>0.61</td>
<td>13.56</td>
<td>53</td>
</tr>
<tr>
<td>36U-4B(a)</td>
<td>0.58</td>
<td>14.13</td>
<td>56</td>
</tr>
<tr>
<td>42U-4B(a)</td>
<td>0.57</td>
<td>14.38</td>
<td>57</td>
</tr>
<tr>
<td>48U-4B(a)</td>
<td>0.56</td>
<td>14.58</td>
<td>58</td>
</tr>
</tbody>
</table>

> 55% of payload units → small accelerations
< 40% of payload units → large accelerations
Suggest: payload units < 40%, ~ 33% is the optimum
**Jelly Roll**

- Jelly Roll-formed Solar Sails

**Hybrid**

- Accelerations stay in the high range of Jelly Roll and Heliogyro with insignificant decreases in accelerations as the size increases.
- The hybrid’s sail loading does not dramatically increase with size.

**Jelly Roll:**

\( \leq 12U \rightarrow \) low to mid-range characteristic accelerations compare to Heliogyro configurations.

**Hybrid:**

Accelerations stay in the high range of Jelly Roll and Heliogyro with insignificant decreases in accelerations as the size increases.

The hybrid’s sail loading does not dramatically increase with size.
**Summary**

**Heliogyro:**

Large accelerations (> ~0.7 mm/s²), suggest < 40% of payload units, ~ 33% is the optimum

**Jelly Roll and Hybrid (Combination of Jelly Roll and Heliogyro)**

Suggest: payload space ~30 – 40% of the payload space to produce > 0.8 mm/s².
Heliogyro-Configured Solar Sail Spacecraft

Peerawan.Wiwattananon@nasa.gov