Heliogyro–Configured Solar Sail Spacecraft

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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.

- Asteroid Mapping
- Asteroid Redirect
- Near Earth Object Monitoring

De-orbit end of life satellites

Image Credit: NASA
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>
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<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: 
\( \leq 12U \rightarrow \) 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/s$^2$), 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/s$^2$. 
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