Mission context

Space propulsion is one of the big steps forward in the area of nanosatellites. It answers to many current scientific and industrial needs, enables new mission concepts such as auto-navigation, space docking, formation flying... Among the various crucial aspects, such as auto-navigation, space docking, formation flying,... Among the various industrial needs, enables new mission concepts with the center of mass of the CubeSat). This is simulated in the figure 1, since it is the most demanding in terms of requirements.

General comparison of CubeSat propulsion systems

Propulsion Subsystems

Chemical
- Compressed gas
- Liquid propellant
- Solid propellant
- Electric propellant
- Electrical

Figure 2: Difference categories of propulsion systems for spacecrafts.

Candidates for our study case

Attitude control with L-μPPT

Attitude control for deep space CubeSat requires propulsion systems:
- Magnetic torquers are irrelevant in the absence of a sufficiently strong and well-known ambient magnetic field;
- Although reaction wheels can easily provide the required control, they need to be decoupled regularly.

Attitude control with L-μPPT is simulated in the following configuration:
- 4 thrusters globally in the main longitudinal axis slightly (configuration for orbit control);
- Thrusters are slightly tilted along a transverse axis to allow 3-axis attitude control.

Figure 6 presents the time needed to perform a certain maneuver.

Most propulsion systems provide only one axis of thrust, hence only orbit control, as shown in figure 6. A propulsion system dedicated to attitude control must be able to maintain the desired attitude despite the undesired torques produced by the main propulsion (caused by the misalignments of the center of mass of the CubeSat). This is shown in figure 7, again using L-μPPT for attitude control. A thrust for the main thruster of 5 mN is considered (equivalent to a CGT) with an angle offset of 3.6 deg and a position offset of 0.9 cm.

Torques produced by the main propulsion system result in a relatively constant pointing offset. Pointing accuracy below 1 deg is sufficient for orbital maneuvers.

Conclusion

ASSESSMENT OF THE PERFORMANCE OF PROPULSION SYSTEMS FOR CUBESAT EXPLORING SMALL BODIES


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Various technologies for propulsion have been developed over the space era. The most common way of classifying them is from their source of energy. Existing or under development propulsion system types for CubeSats are highlighted in figure 2. Their performances are displayed in figure 3, where the specific impulse is represented as well as the thrust.

High thrust level > high agility but low accuracy

High specific impulse > high Δv with small amount of propellant.

The trend in figure 3 clearly shows that electrical propulsion is the best solution, although they often consume a huge amount of power. Mono- and bi-propellant systems are more interesting for high impulse maneuvers, while cold gas systems suffer from low Δv capabilities.

Investigating the use of a CubeSat to perform geodesy of a small body requires to identify propulsive strategies presented in figure 4:
- The CubeSat is released nearby the asteroid and the autonomous GNC shall allow TCMs in its vicinity;
- A propulsion system dedicated to attitude control when the main propulsion system is fired. The L-μPPT propulsion system, currently at TRL 4, meets this requirement.

Table 1: Characteristics of the propulsion systems meeting the attitude control requirements.

<table>
<thead>
<tr>
<th>System</th>
<th>Mass</th>
<th>Power</th>
<th>Multi-axis</th>
<th>Δv</th>
<th>ΔIsp</th>
</tr>
</thead>
<tbody>
<tr>
<td>LESIA 500</td>
<td>1.5 kg</td>
<td>300 W</td>
<td>Yes</td>
<td>2 m/s</td>
<td>1000 s</td>
</tr>
<tr>
<td>L-μPPT</td>
<td>1.5 kg</td>
<td>300 W</td>
<td>Yes</td>
<td>2 m/s</td>
<td>1000 s</td>
</tr>
<tr>
<td>TILE-500</td>
<td>1.5 kg</td>
<td>300 W</td>
<td>Yes</td>
<td>2 m/s</td>
<td>1000 s</td>
</tr>
</tbody>
</table>

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