Fuel Minimization for Constellation Phasing
Maintenance of Multi Classes of Low-Cost Satellites

Jer Ling
National Space Organization (NSPO)
Taiwan
2006.8.17
FORMOSAT-3
Successfully Launched in 14 April 2006

- An international cooperation program between NSPO and UCAR (University Corporation for Atmospheric Research), USA

- The constellation of 6 low-earth-orbit (LEO) micro-satellites

- Each micro-satellite is cylindrical with weight 70 Kg, diameter 116 cm, height 18 cm

- Satellite parking orbit is approximate 500Km with 72-degree inclination.

- Each satellite performs orbital raising to get into 6 separate orbital planes nominally phased 24°. The mission orbit is 700-800 km circular.

- Mission life: 2 years (design life: 5 years)

- Launched on 14 April 2006, and successfully started missions
Argo

Next phase mission for NSPO to be competitive

Mission Objectives

– To establish a state-of-the-art reusable heritage bus platform for future missions
– To conduct leading-edge scientific research
– To gain commercial rewards and international cooperation with RapidEye constellation
Argo

- A Greek mythology
- The ship of Jason and his followers in quest of the Golden Fleece
  - Name of a ship
  - Sailed by a group of braves for an adventure

Remote sensing & Space science missions
RapidEye Constellation

- Originally 5 satellites
- 5 + 1 Constellation Re-shaping
- Challenges for the low-cost satellite on phasing maintenance
  - Difficult for high accuracy orbit determination & control
  - Different start insertion plane
  - Max mission cycles
  - Different drag
Orbit Phasing Requirement

1/6 equator

10%
Phasing Maintenance Operations

<table>
<thead>
<tr>
<th>If Argo fly lower than the other satellites by the distance of:</th>
<th>The time for ground track drift out ±10% of the nominal distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2km</td>
<td>1 day</td>
</tr>
<tr>
<td>500m</td>
<td>10 day</td>
</tr>
<tr>
<td>200m</td>
<td>24 day</td>
</tr>
<tr>
<td>100m</td>
<td>37 day</td>
</tr>
</tbody>
</table>

Even with the small altitude difference, the orbit maintenance operations are still needed too frequently.
Wait-and-Hit

Wait-and-Hit (W&H) developed to minimize the phasing maintenance efforts

Phasing needed when Argo coincides with VRE-1 or VRE-2
W&H Step 1

- Argo satellite 200m above RapidEye and at the front 10% limit
W&H Step 2

- Argo satellite is going downward and caught by the later Virtual RE-2
As Argo satellite speeding up after passing the EXACT RapidEye plane, it catches the former RE-1
W&H Step 4

- Virtual RE-1 coincides with Argo again, and time for adjustment
Conclusions

- Simulation shows it can take as many as 230 days for one cycle of W&H, i.e. to adjust the phasing for 230 days a time.
  - Initial orbit correction requires only 200m accuracy,
- The algorithms can be applied to the general cases of low-cost satellite constellation,
  - Satellites with no sophisticated propulsion and orbit control hardware.