STK in the Master in Space Systems (MUSE)

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Briefing on the Master in Space Systems (MUSE)
Research on Space at IDR/UPM

• Iniciated in the late 70s
  – Liquid bridges under microgravity
  – First Spanish experiment carried out in Space (1983)

• Handbook of Spacecraft Thermal Control (ESA)
Research on Space at IDR/UPM

- UPMSat-1 (1995)
Research on Space at IDR/UPM

- Rosetta (2004)
- SUNRISE (2009)
- Solar Orbiter (2018)
Research on Space at IDR/UPM

- EPD (2018)
  - EPT-HET
  - STEP
- RAMAN (2018)
  - iOH
- NOMAD (2016)
- EUCLID (2020)
Research on Space at IDR/UPM

- UPMSat-2 (2017)
IDR/UPM Institute:

• Human resources
  – 47 researchers
  – Core of 7 professors

• Academic experience in space systems
  – Ph.D./Master final degree projects

• First official master’s degree program by a research institute
Current and future integration of STK software in the Master’s Program
Master’s program:

- 2-year program
- 120 ECTS
  - Advanced Mathematics (12 ECTS)
  - Space Projects Definition (22.5 ECTS)
  - Systems Engineering (25.5 ECTS)
  - Spacecraft Subsystems (28.5 ECTS)
  - Case Studies and Master Thesis (31.5 ECTS)
- Project based learning
Master’s program:

- Space Projects Definition (22.5 ECTS)
  - Space environment and mission analysis
  - High speed aerodynamics and atmospheric reentry phenomena
  - Vibrations and aeroacoustics
  - Space materials
  - Graphic design for aerospace engineering
Master’s program:

- Systems Engineering (25.5 ECTS)
  - Systems engineering and project management
  - Quality assurance
  - Space industry and institutions seminars
  - Production technologies
  - Space integration and testing
  - Spacecraft propulsion and launchers
Master’s program:

- **Spacecraft Subsystems (28.5 ECTS)**
  - Orbital dynamics and attitude control
  - Heat transfer and thermal control
  - **Power subsystems**
  - Space structures
  - Communications
  - Data housekeeping
Master’s program:

• Case Studies and Master Thesis (31.5 ECTS)
  – Testing the attitude positioning photodiodes of the UPMSat-2
  – Analysis, characterization and testing of the UPMSat-2 Reaction Wheel payload
  – Harness design for the UPMSat-2
  – Orbit analysis of the UNION/Lian-Hé satellite at the CDF
Example of a Case Study by MUSE students using STK
Access – Segment Earth
Accesses study

- Two confirmed stations: Madrid and Beijing

One possible station: Buenos Aires

- Calculate accesses times
- Determine accesses sequence and periodicity
- Maximum and minimum time between accesses
- Study how Buenos Aires station would increment the availability
Nodal Precession

\[ \Delta \lambda = -23.55^\circ \]
Orbit study

- Orbit duration 1 h 32 min 23.434 s.
- 15.59 orbits per day
- Nodal precession $\Delta \lambda = -23.55^\circ$
- Repeatability:

<table>
<thead>
<tr>
<th>Period</th>
<th>Orbits</th>
<th>Error in repetition</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 d 22 h 49 min 57.985 s</td>
<td>46</td>
<td>-3° 21’</td>
</tr>
<tr>
<td>3 d 21 h 55 min 49.501 s</td>
<td>61</td>
<td>+3° 23’</td>
</tr>
<tr>
<td>6 d 20 h 45 min 47.485 s</td>
<td>107</td>
<td>+2’</td>
</tr>
</tbody>
</table>
Sequences of accesses

Example of orbit 🇨🇳 ➔ 🇦🇷

Example of orbit 🇦🇷 ➔ 🇨🇳
Sequences of accesses

Example of orbit 🇪🇸 → 🇪🇸

Example of orbit 🇪🇸 → 🇦🇷
Access Schedule

RAAN of the orbit

Δλ = -23.55°
Some quick conclusions:

- Max access time 6 min 37 seconds
- Average access time 5 min 48 seconds
- Access time 13.7 hours per month
- Max time without access 9 h 38 min

113 < RAAN < -118º  Madrid → Buenos Aires
5 or 6 complete orbits without access
Mission Lifetime
Lian-He mission lifetime study

– Initial orbit of the spacecraft is low, only 400 km
– Study of the lifetime is crucial

Lian-He mission characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drag coefficient</td>
<td>$C_D$</td>
<td>2.2</td>
</tr>
<tr>
<td>Solar radiation coefficient</td>
<td>$C_r$</td>
<td>1</td>
</tr>
<tr>
<td>Frontal Area</td>
<td>$A_f$</td>
<td>0.25 m$^2$</td>
</tr>
<tr>
<td>Mass</td>
<td>$M$</td>
<td>50 kg</td>
</tr>
<tr>
<td>Solar flux sigma</td>
<td>$\sigma$</td>
<td>5 $\sigma$</td>
</tr>
</tbody>
</table>
Other missions study

Other missions have been studied as reference

<table>
<thead>
<tr>
<th>Mission</th>
<th>Real lifetime</th>
<th>Lifetime prediction Solar Flux CCSI</th>
<th>Lifetime prediction Solar Flux Schatten</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUTE-1.7 + APD</td>
<td>1342</td>
<td>1131.5</td>
<td>766.5</td>
</tr>
<tr>
<td>Genesat 1</td>
<td>1327</td>
<td>1679</td>
<td>1533</td>
</tr>
<tr>
<td>Aerocube 3</td>
<td>597</td>
<td>520.5</td>
<td>584</td>
</tr>
<tr>
<td>Hayato</td>
<td>39</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>Waseda-sat2</td>
<td>53</td>
<td>22</td>
<td>21</td>
</tr>
<tr>
<td>Negai</td>
<td>37</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

Jacchia 1970 Lt with Schatten models will be used because they produce conservative results.
Lian-He mission lifetime study

<table>
<thead>
<tr>
<th>Launch date</th>
<th>Lifetime in days</th>
<th>Lifetime in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 – 01 – 01</td>
<td>683</td>
<td>2.30</td>
</tr>
<tr>
<td>2018 – 04 – 01</td>
<td>687</td>
<td>2.46</td>
</tr>
<tr>
<td>2018 – 08 – 01</td>
<td>640</td>
<td>2.41</td>
</tr>
<tr>
<td>2019 – 01 – 01</td>
<td>654</td>
<td>2.45</td>
</tr>
</tbody>
</table>

![Graph showing the lifetime of Lian-He mission](image-url)
Eclipses and power produced by the panels
Eclipses:

- Necessary for battery sizing
- Previous to power study

### Length of the Eclipse

<table>
<thead>
<tr>
<th>Altitude (km)</th>
<th>Max (min)</th>
<th>Min (min)</th>
<th>Average (min)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>37.28</td>
<td>26.67</td>
<td>35.64</td>
<td>40.30</td>
</tr>
<tr>
<td>250</td>
<td>36.91</td>
<td>24.58</td>
<td>35.04</td>
<td>39.17</td>
</tr>
<tr>
<td>300</td>
<td>36.61</td>
<td>22.54</td>
<td>34.51</td>
<td>38.15</td>
</tr>
<tr>
<td>350</td>
<td>36.36</td>
<td>21.00</td>
<td>34.03</td>
<td>37.20</td>
</tr>
<tr>
<td>400</td>
<td>36.14</td>
<td>20.03</td>
<td>33.61</td>
<td>36.33</td>
</tr>
</tbody>
</table>

Altitude - 400 km

Graph showing eclipse duration over orbits with max, min, and average values for different altitudes.
Solar Power:

- Solar panels in the laterals of the satellite
- Two configurations of panels
- Z axis pointing to Nadir
- Analysis of the free axis 0º, 22.5º and 45º
- Three altitudes
- Effective area of the faces 60%
- Panel efficiency of 28%

\[ P = \eta \cdot I \cdot A_{ef} \cdot E \]
**Summary**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed 0°</td>
<td>30.39</td>
<td>45.37</td>
<td>17.99</td>
<td>65.93</td>
</tr>
<tr>
<td>Closed 22.5°</td>
<td>29.83</td>
<td>48.26</td>
<td>20.80</td>
<td>70.49</td>
</tr>
<tr>
<td>Closed 45°</td>
<td>29.67</td>
<td>47.67</td>
<td>22.21</td>
<td>67.30</td>
</tr>
<tr>
<td>Open</td>
<td>42.68</td>
<td>50.37</td>
<td>24.03</td>
<td>103.63</td>
</tr>
</tbody>
</table>
Future cases of study?

• Coverage analysis
• Evaluate Communications Links
• Launch
• Precise attitude and orbit propagation
• ...

2016 International Users' Conference
More information

• MUSE: http://muse.idr.upm.es/
• IDR: http://www.idr.upm.es/

Bibliography

• B. Torres, A. Rodríguez, A. G. Maldonado, N Fernandez de Bobadilla. Orbit study and analysis of the Lian He - Union mission.
Thank you