Electric propulsion as game changer for CubeSat: mission analysis with LOTOS

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Outline

• Astos Solutions and Products
• State of art
• Motivation
• EP for orbit change
• Orbit change examples
  • Micro satellite
  • Cubesat
• Space tug example
• LOTOS
  • Introduction
  • Operational mode
• Conclusion

Credits:
- Fachhochschule Wiener Neustadt
- AOBA VELOX III
- Aerospace Corporation
- SSTL
Astos Solutions overview

- SME with sites in Unterkirnach (DE), Stuttgart (DE), Bucharest (RO)
- Spin-Off of the Univ. of Stuttgart, standalone company since 2006
- Roots of Astos Solutions go back to 1989
Product overview
State of the art – Propulsion

What about Cube-sat and Micro-sat?:

- Several commercial options
  - BUSEK
  - Aerojet Rocketdyne
  - Accion Systems
  - Sitael
  - Others ...

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<tr>
<th>Product Image</th>
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- University studies and test (e.g. MIT, Michigan)

Credits: Accion Systems

Credits: Aerojet Rocketdyne

Credits: Sitael

Credits: BUSEK
State of the art – Application

Low-thrust is used in space:
• Orbit change till target orbit (GTO-GEO)
• Position and Attitude control during operational phase
• De-orbit or graveyarding at end-of-life

Near future scenarios:
• Orbit change till target orbit (after piggy-back)
• Space tug for delivery and service

Credits: Astos Solutions LOTOS
Motivation

All these scenarios requires:
• Optimization and analysis of high-fidelity transfer trajectories
• Optimized maneuver planning
• Software for Guidance & Navigation
• Mission analysis

Is there budget/time for development of in-house tools?
COTS solution – LOTOS

- Hybrid transfers
- Electric transfer
- Controlled 6DoF attitude
- Verification of trajectories
- Database
- Post-processing
- Reports
- Windows & Linux platform
LOTOS – operational aspects

Once the trajectory (and satellite) is optimized, operational aspects have to be considered:

- Re-optimization of trajectory after separation from launcher to consider injection errors.
- Periodic re-optimization of trajectory to account for perturbations, attitude errors and underperformance of propulsion.
- New maneuver plan of next cycle is uploaded to the satellite.

Credits: Safran
Electric Propulsion for orbit change – Example

Several satellites are launched in a single orbit:

- PSLV
- Soyuz
- Even more in the future (Falcon, Electron, etc.)

Credits: Glavkosmos

Credits: Rocket Lab
EP for orbit change – Microsat example

- PLSV delivery at 800 km SSO → Not compliant with end-of-life regulations.

- Target orbit 500 km SSO
  - Satellite mass 50 kg
  - Power = 200 W
  - Isp = 1400 s (Hall)
  - Thrust = 0.013 N

- Final Sat mass = 48.9 kg
- Transfer duration = 12.8 days
- Delta V = 291 m/s

Credits: AS LOTOS
EP for orbit change – 3U Cubesat example

• PLSV delivery at 570 km SSO → Not compliant with end-of-life regulations.

• Target orbit 500 km SSO
  • Satellite mass 5 kg
  • Power = 15 W
  • Isp = 800 s (Electrospray)
  • Thrust = 0.7 mN

• Final Sat mass = 4.954 kg
• Transfer duration = 5.9 days
• Delta V = 72 m/s

Credits: AS LOTOS
Space tug – Cubesat/Microsat applications

- Delivery of a satellite to its final orbit
- Constellation deployment without impacting life-time of satellites
- De-orbit of not active satellites
- Service of satellites in LEO for repositioning, life-extension, repair and graveyarding.

Credits: AS LOTOS
Space tug – Does it make sense?

- Microsat example from 800 km to 500 km
  - Satellite mass 50 kg
  - Tug mass = 50 kg
  - Power = 200 W
  - Isp = 1400 s (Hall)
  - Thrust = 0.013 N

- Final Tug mass = 47.9 kg
- Transfer duration = 25.6 days

- Tug return to 800 km SSO
  - Final Tug mass = 46.8 kg
  - Transfer duration = 13.4 days
Conclusion

• Electric propulsion is a well proven technology, the miniaturisation of it allows the implementation on micro-satellites and cubesats.
• This allows constellation deployment, end-of-life graveyarding and modification of orbit parameters reached by piggy-back deployment.
• Preliminary trajectory optimizations show interesting results for micro-satellites and cubesats.
• Question: are the advantages repaid by the propulsion sub-system cost?
• The application of an electric propulsion Tug is questionable for micro-satellites, not interesting for cube-sat due to volume and mass limitations.
The increased complexity of mission analysis and trajectory optimization requires experience and powerful tools for the design and operation of such vehicles.

Question: **what is cheaper and faster, in-house or COTS software?**

LOTOS can be a solution:
- Simulation, optimization and analysis
- Electric and hybrid transfer
- It supports spacecraft operations
Leadership requires solutions

For a live demo and more information, please visit us at stand J20.