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

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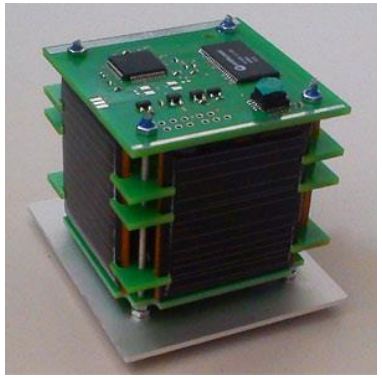
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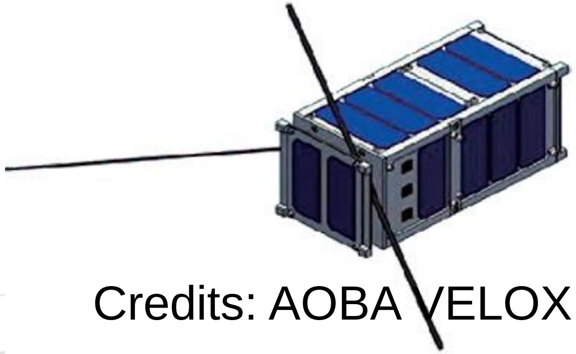
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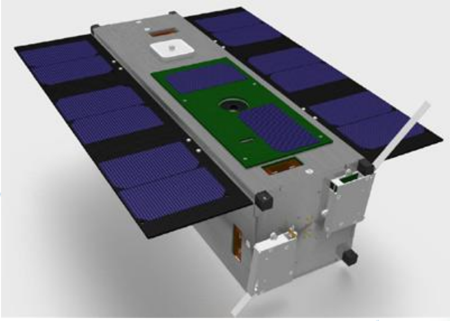
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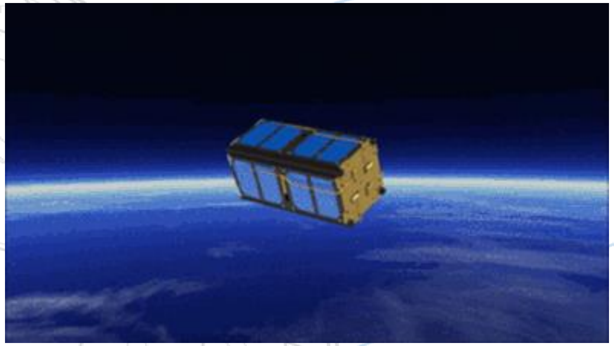
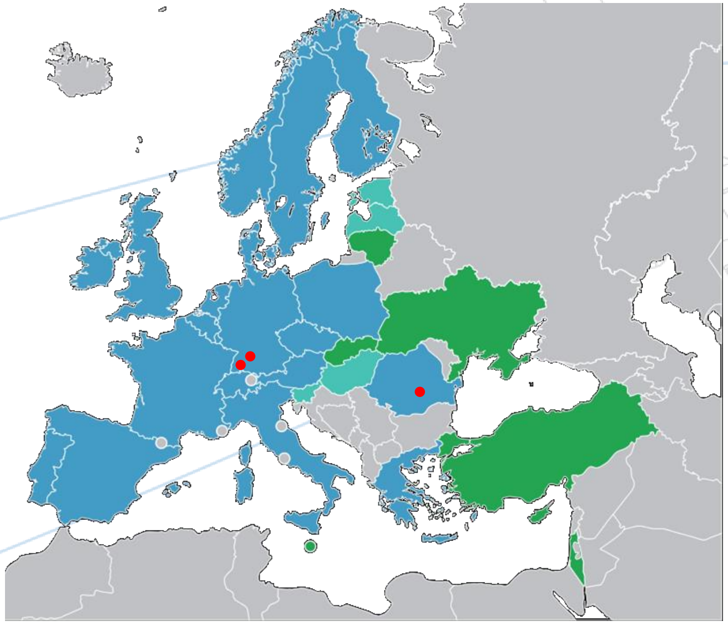

Credits: Fachhochschule Wiener Neustadt


Credits: Aerospace Corporation

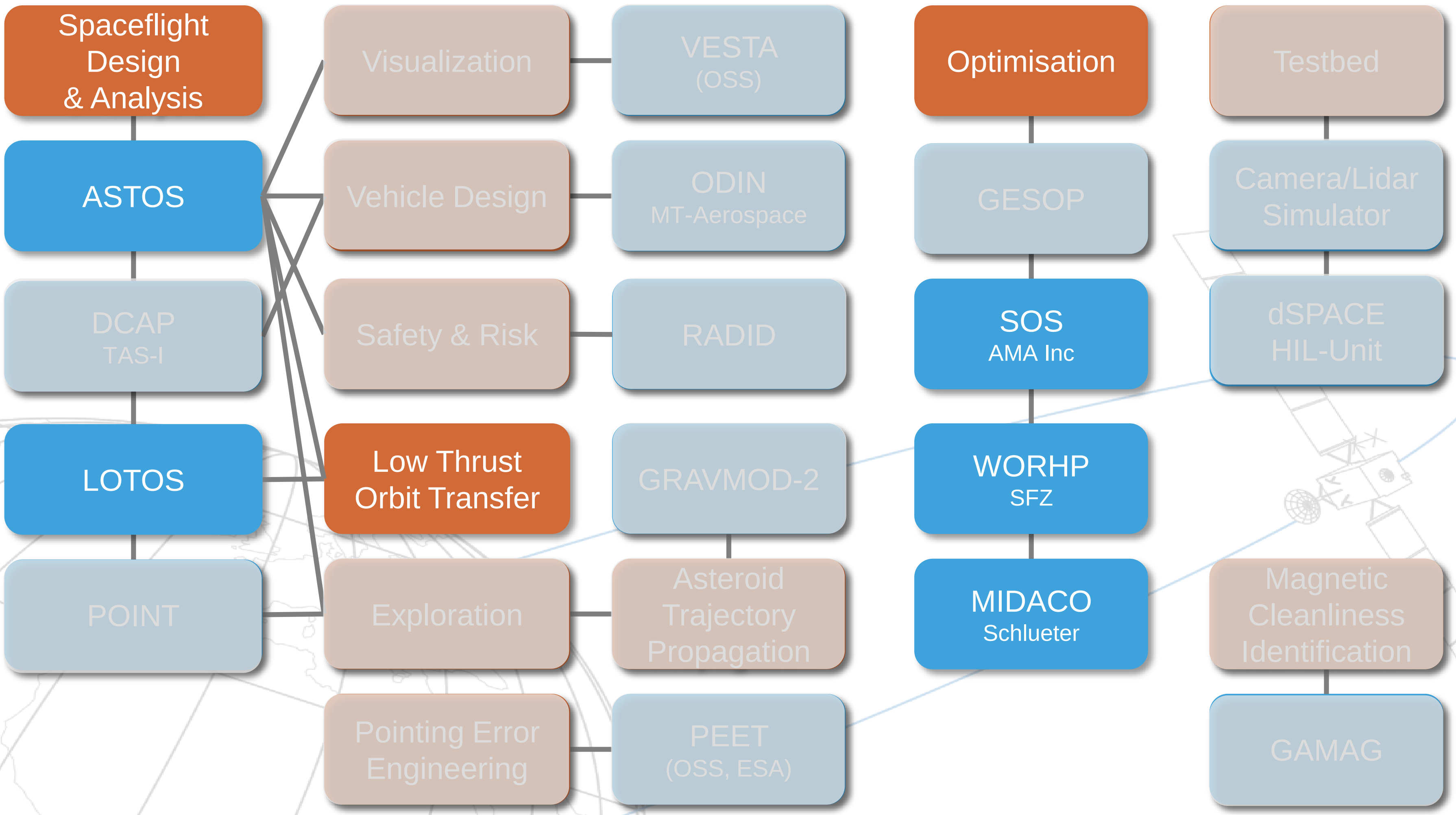
Astos Solutions overview

- 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

Office in Stuttgart



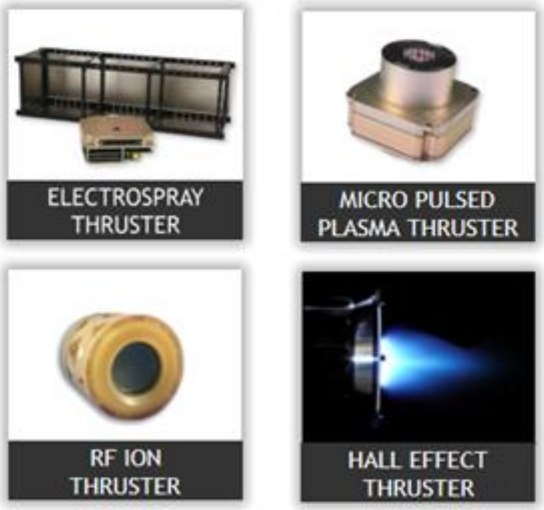
Product overview



State of the art – Propulsion

What about Cube-sat and Micro-sat?:

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

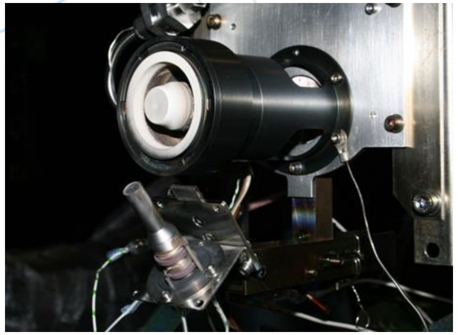


Credits: BUSEK

Product Image	Product Number
	PRS-101
	MR-502

Credits: Aerojet Rocketdyne

Credits: Accion Systems



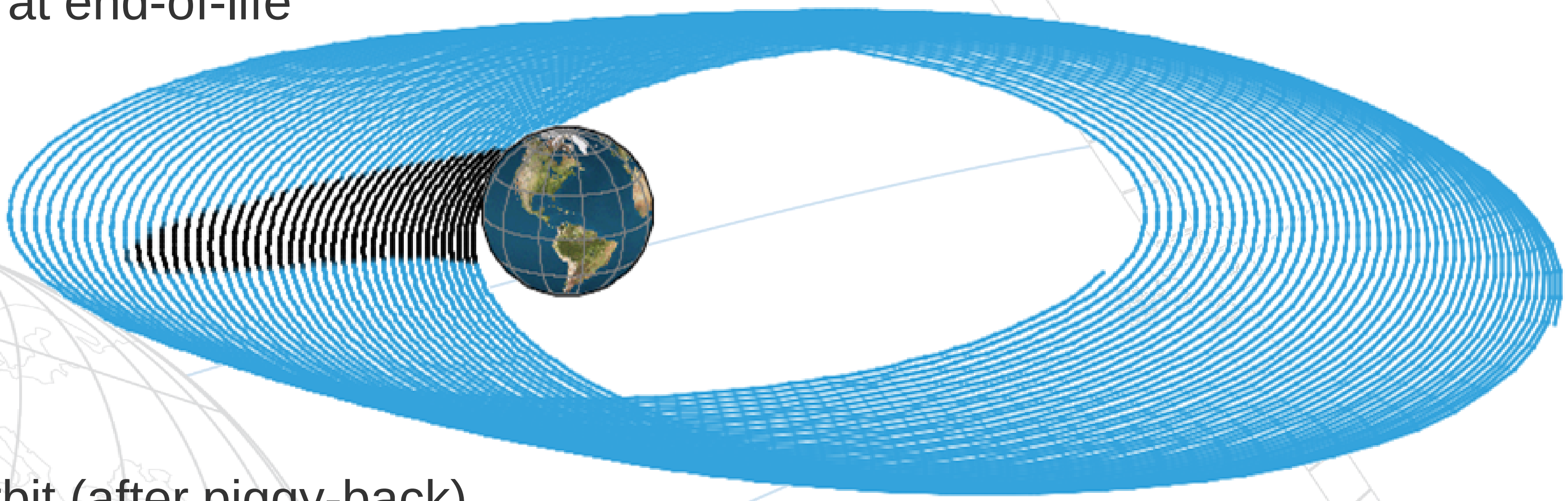
Credits: Sitael

- University studies and test (e.g. MIT, Michigan)

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



Credits: Astos Solutions LOTOS

Near future scenarios:

- Orbit change till target orbit (after piggy-back)
- Space tug for delivery and service

Motivation

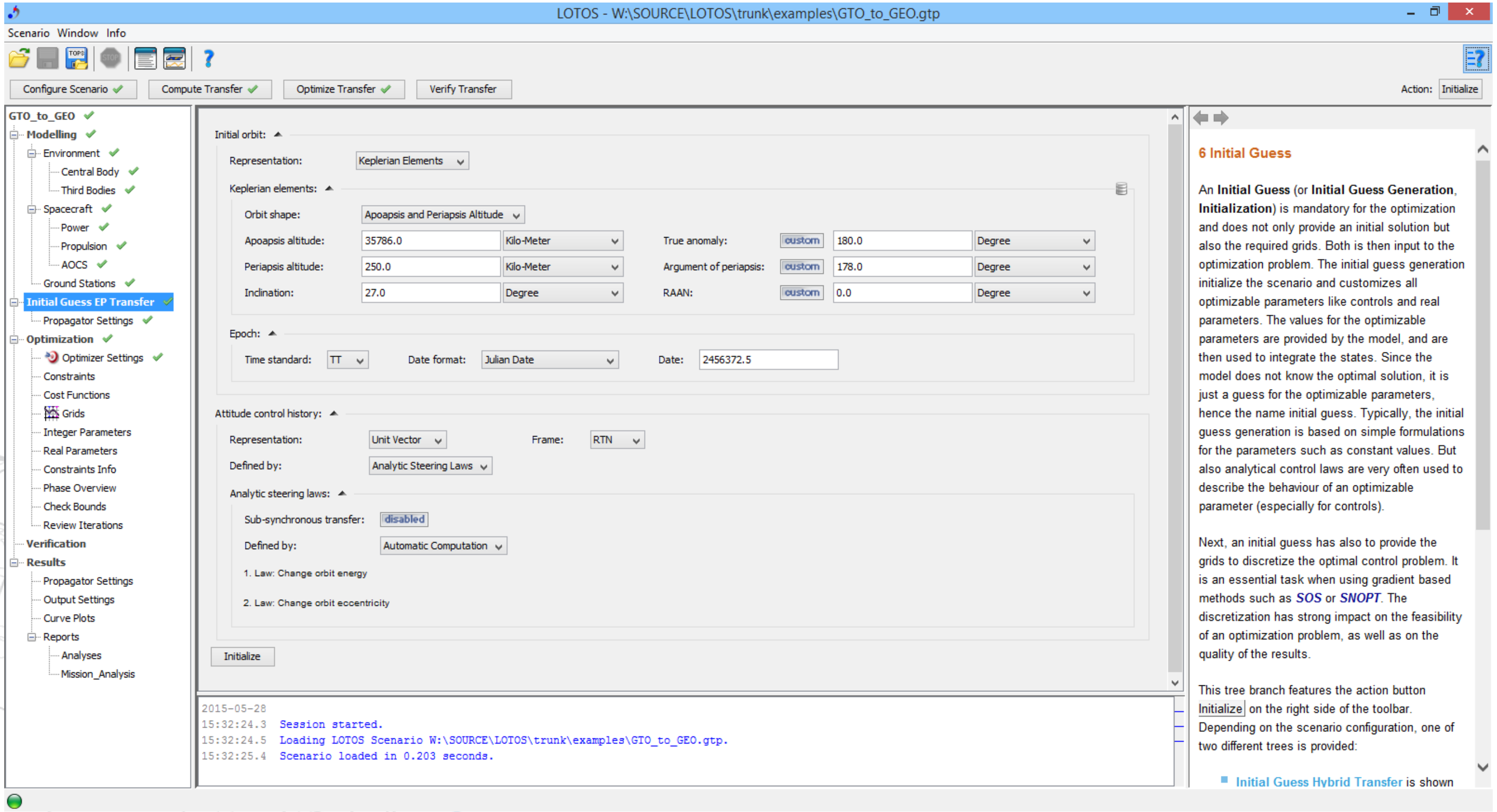
All these scenarios requires:

- 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

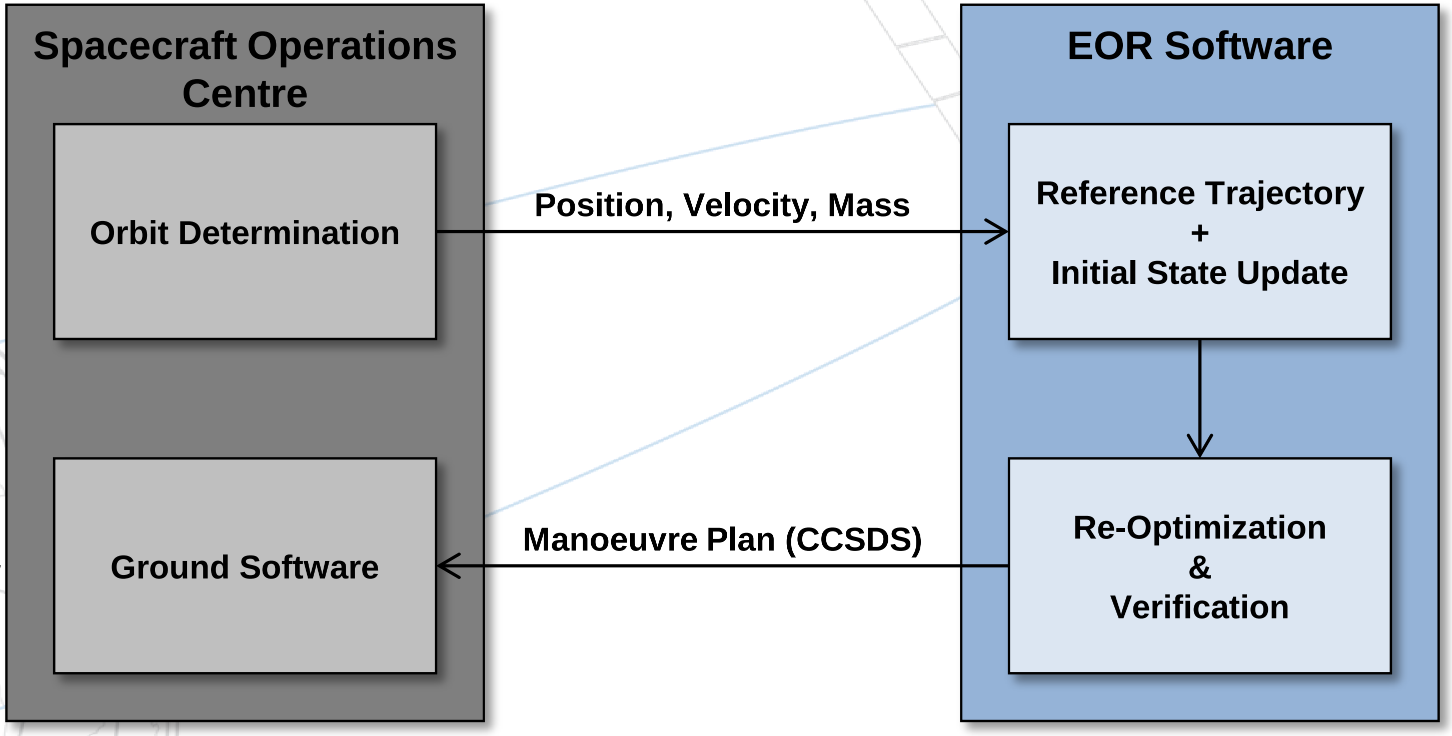


LOTOS – operational aspects

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.

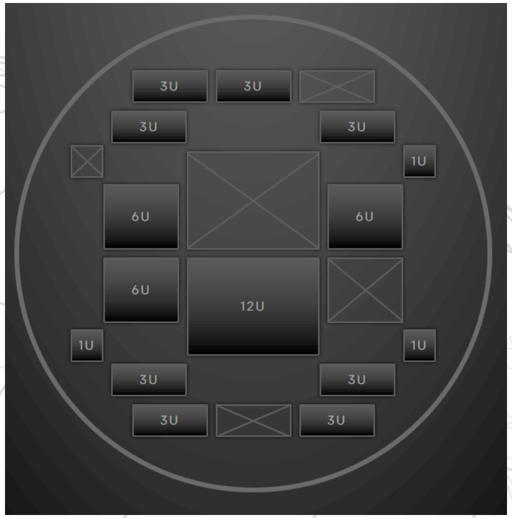
Credits: Safran



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: Rocket Lab

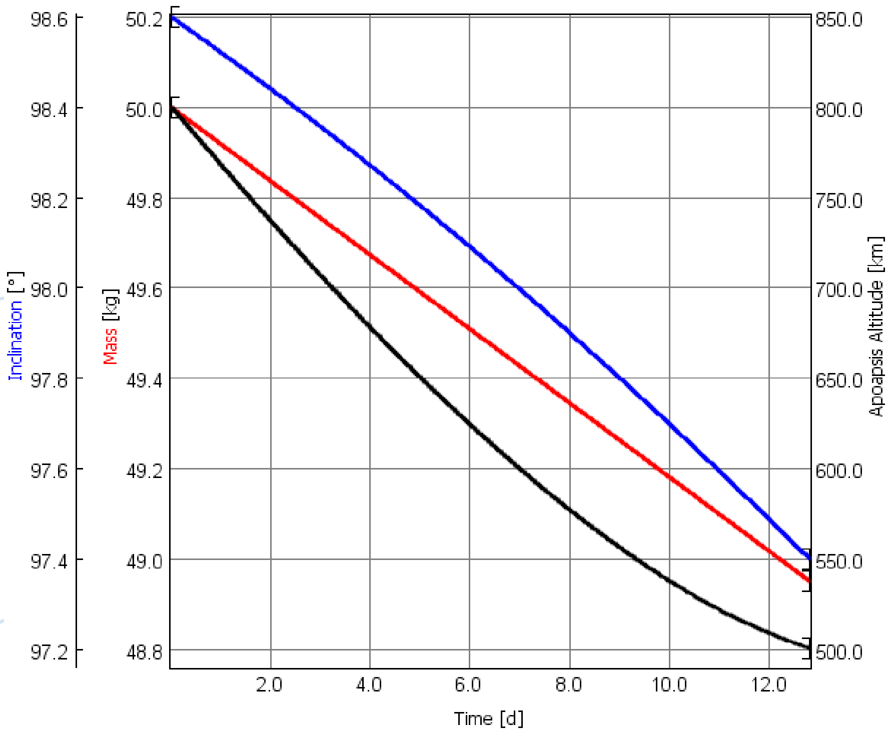
Credits: Glavkosmos

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**



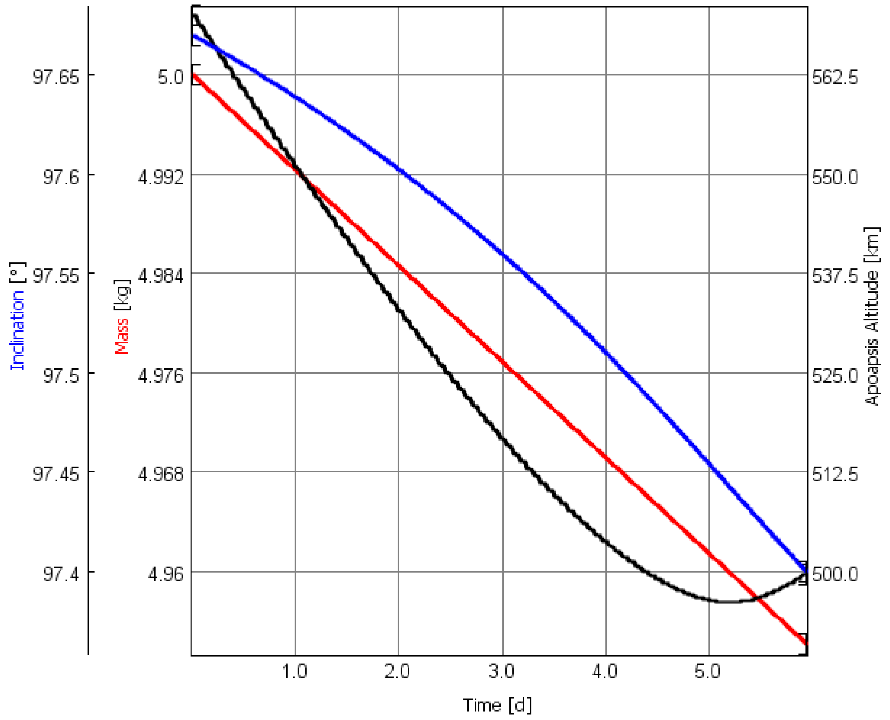
Credits: AS LOTOS

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

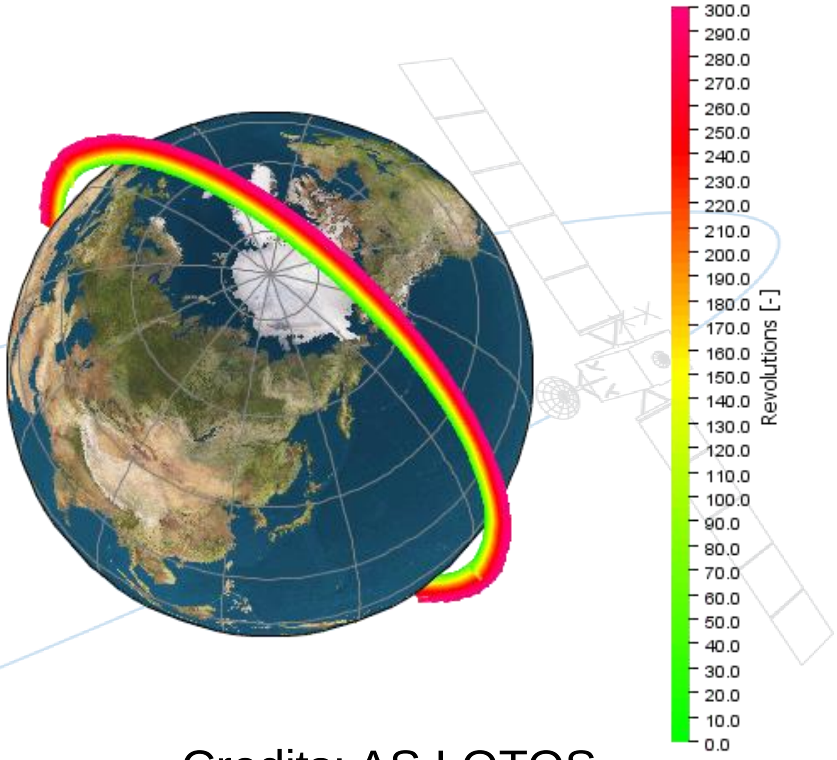
  - **Final Sat mass = 4.954 kg**
  - **Transfer duration = 5.9 days**
  - **Delta V = 72 m/s**



Credits: AS LOTOS

Space tug – Cubesat/Microsat applications

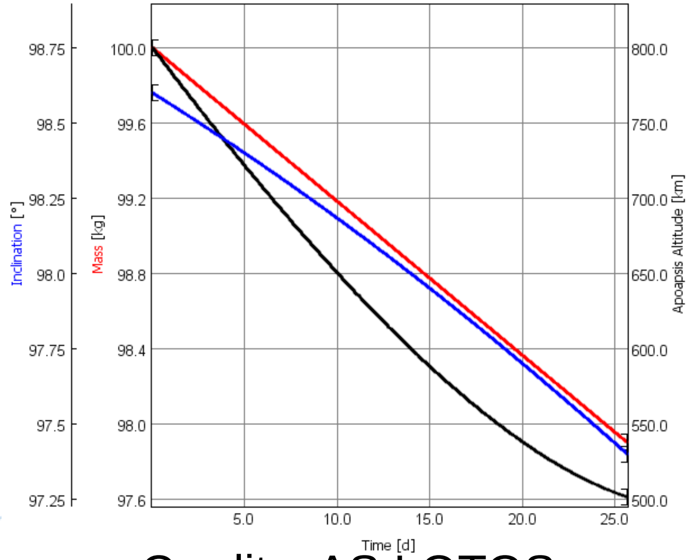
- Delivery of a satellite to its final orbit
- Constellation deployment without impacting life-time of satellites
- De-orbit of not active satellites
- *Service of satellites in LEO for repositioning, life-extension, repair and graveyarding.*



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**



Credits: AS LOTOS

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

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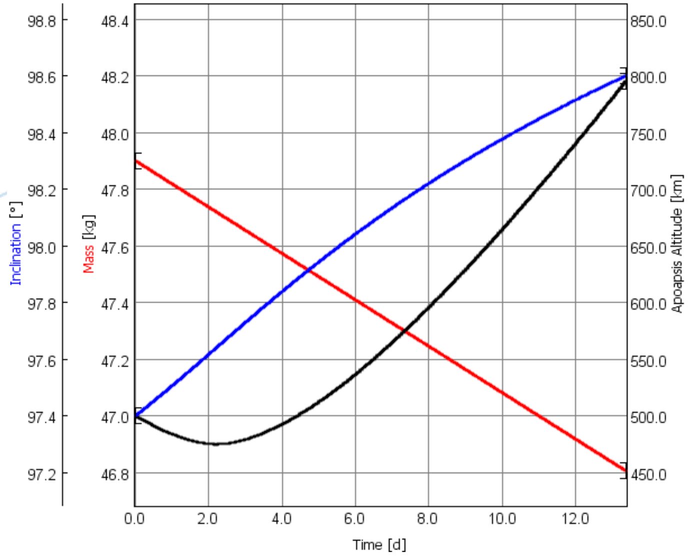

Conclusion

- 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 grave yarding 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.

Conclusion

- 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

you!

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