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Exploring New Lagrangian Cyclers to Enhance Science: Communications with CubeSat Technology

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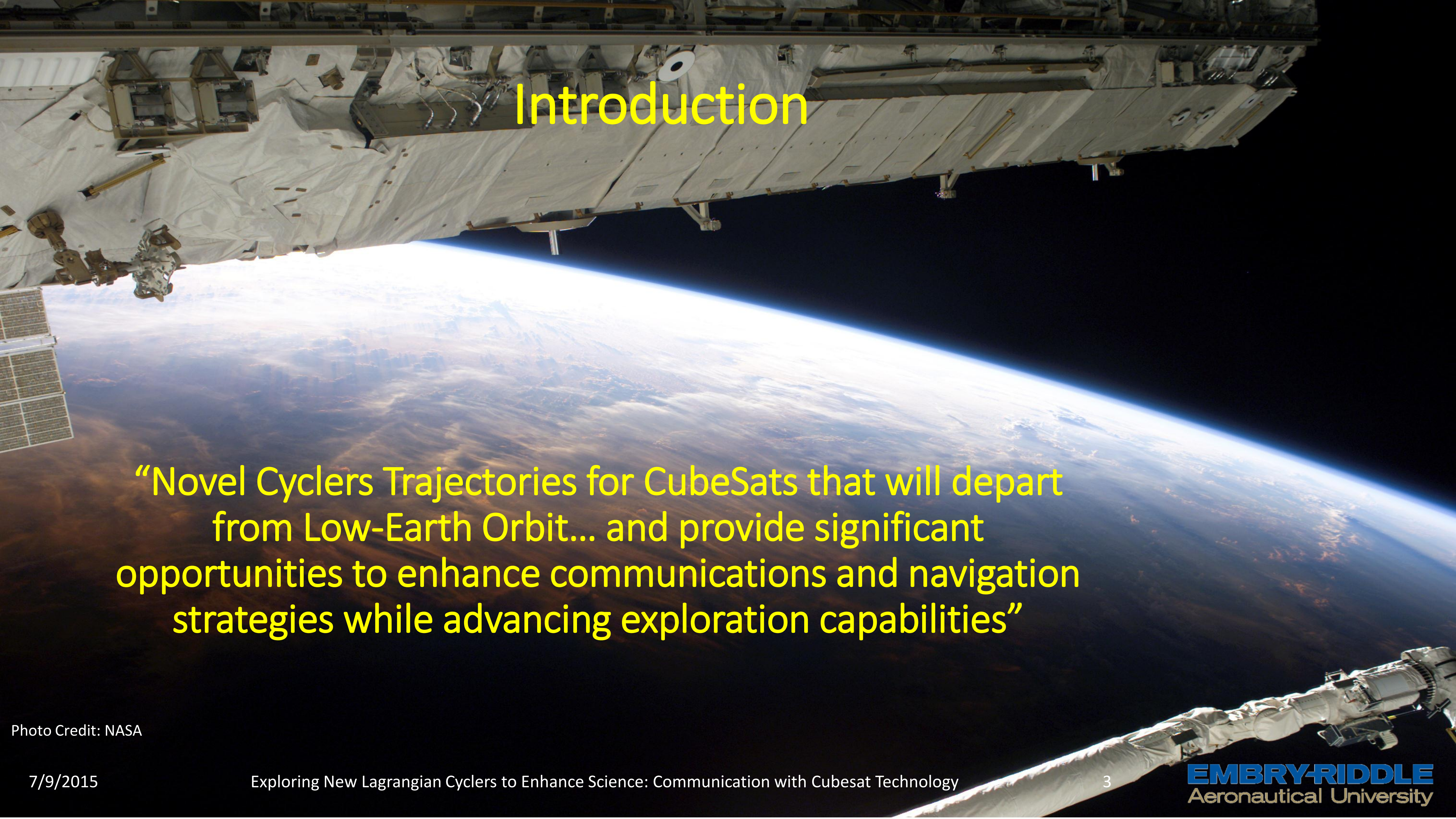
Outline

- Introduction
- CubeSat Technology
- Mathematical Model
- Results (Matlab and STK)
- CubeSat Performance
- Future Work: Applications
- References

Photo Credit: NASA



Introduction

"Novel Cyclers Trajectories for CubeSats that will depart from Low-Earth Orbit… and provide significant opportunities to enhance communications and navigation strategies while advancing exploration capabilities"

Photo Credit: NASA

CubeSat Technology

- Developed by Cal Poly and Stanford University
- Unit: 1U (10cm x 10cm x 10cm) Small Spacecraft
- Accessible for Public, Industry and Government
- High Asset for Spacecraft Flight Opportunities and mission development
- Low Cost

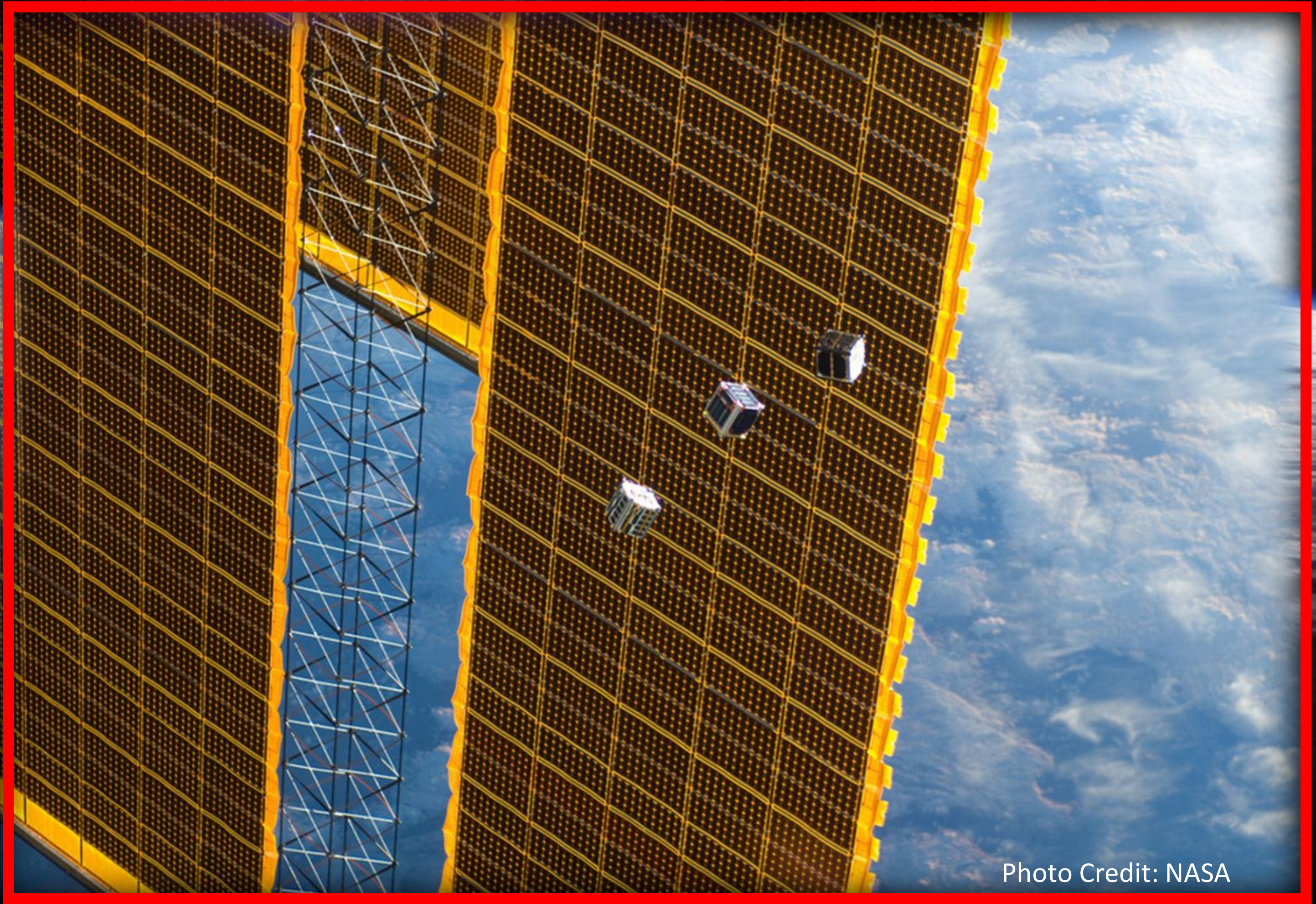


Photo Credit: NASA

Mathematical Model

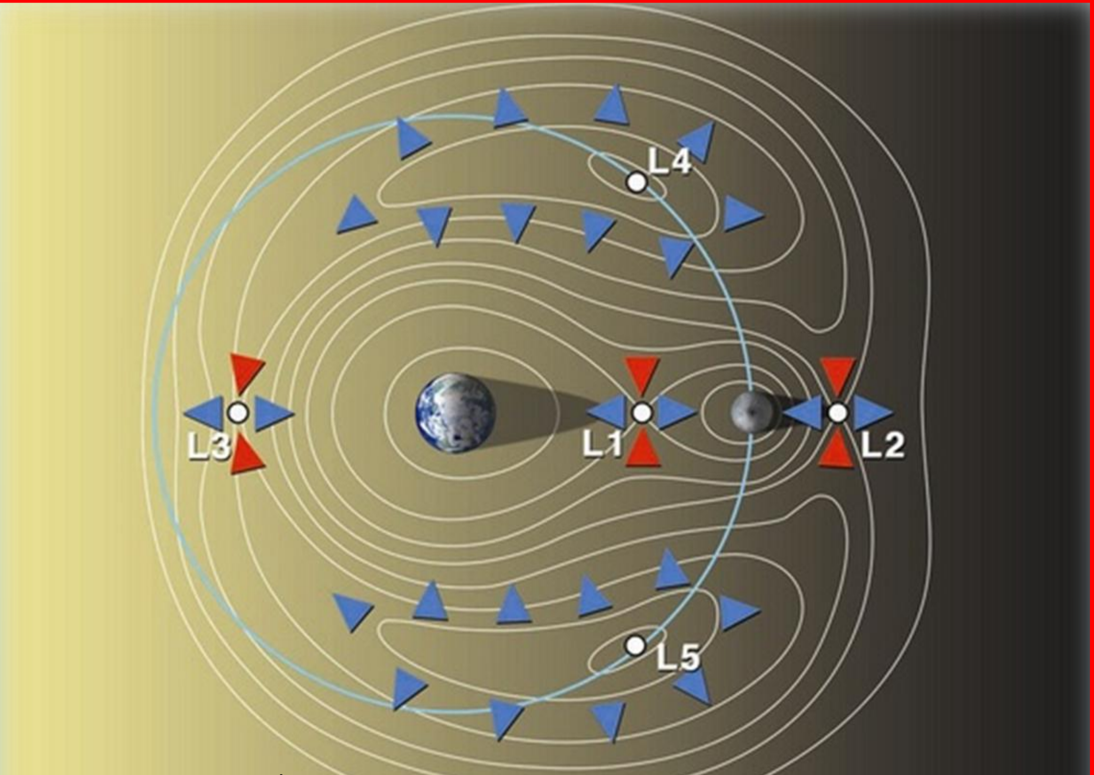
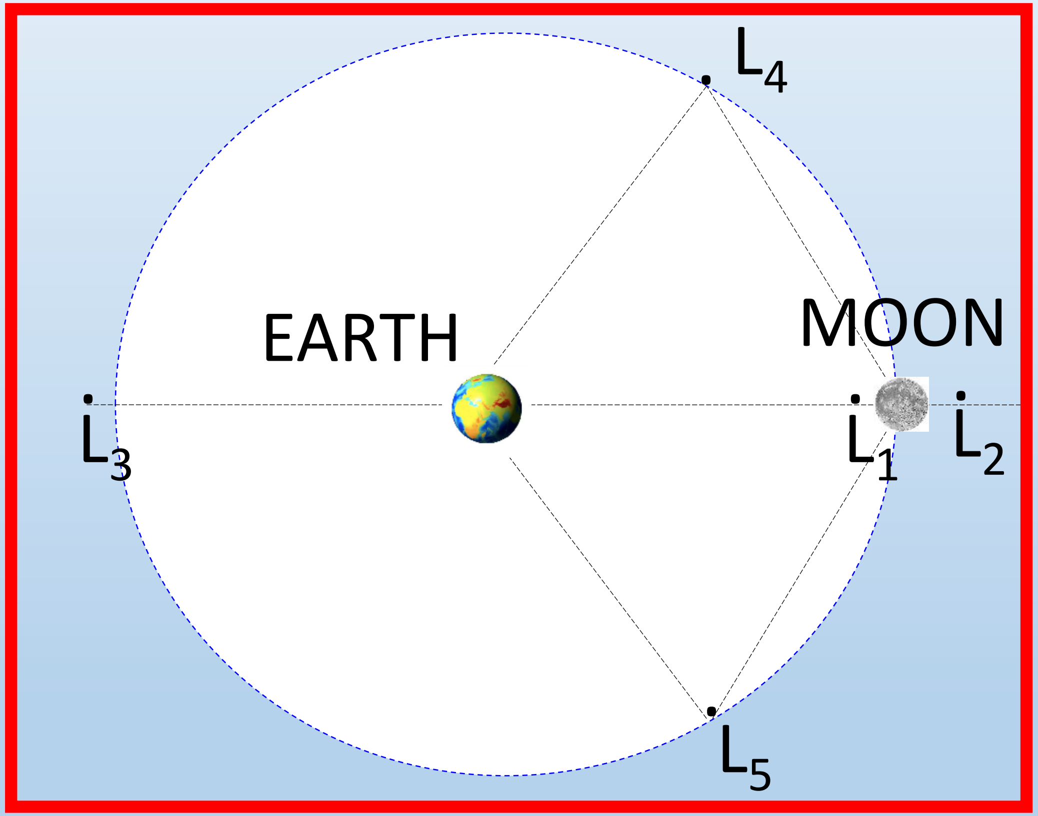
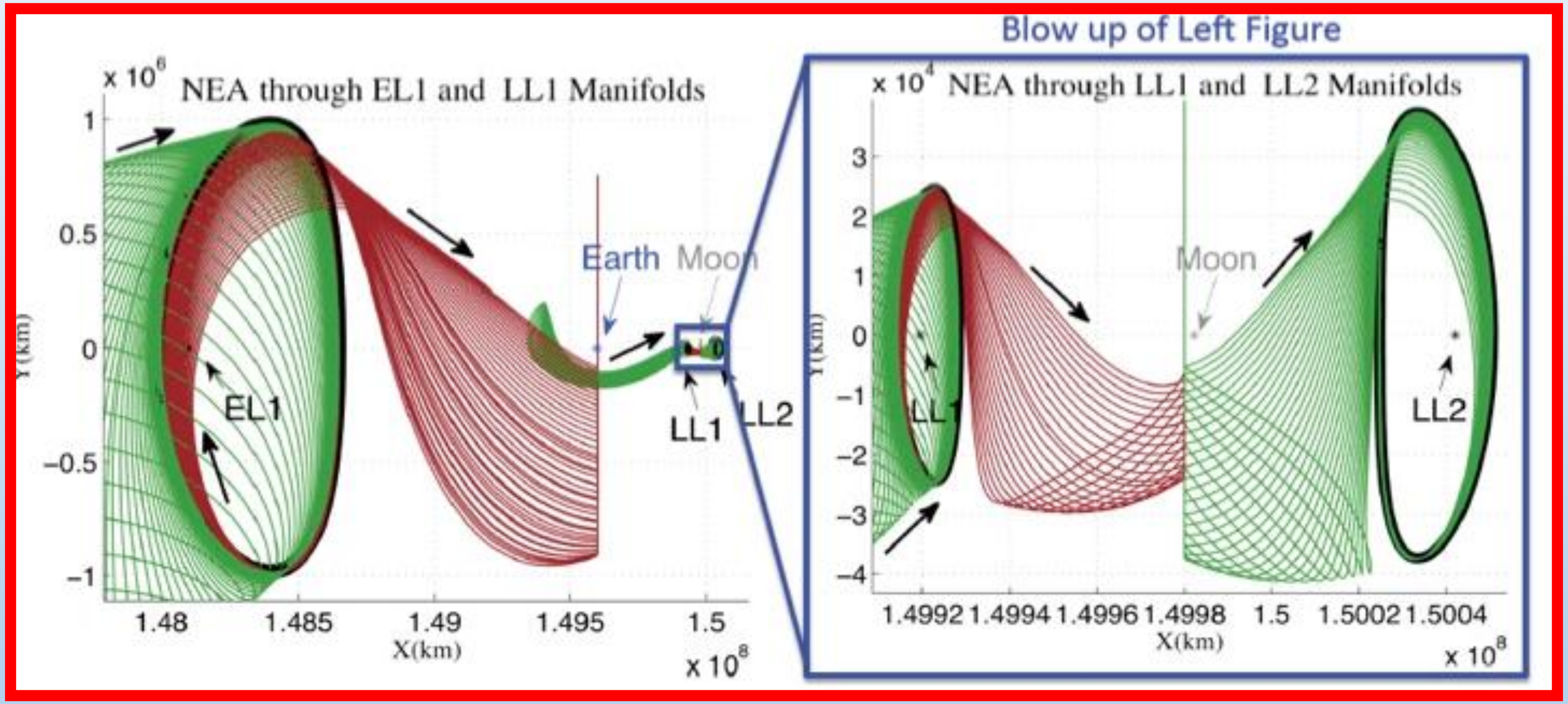


Photo Credit: NASA / LPI-JSC



Mathematical Model



Motion of infinitesimal mass in the rotation frame can be described by the governing equation of motion:

- **Circular Restricted Three-Body Problem (CRTBP)**
  - Earth, Moon and CubeSat
  - Rotating frame

$$\ddot{x} - 2\dot{y} = x - (1-\mu)\frac{x - x_1}{r_1^3} - \mu\frac{x - x_2}{r_2^3}$$

$$\ddot{y} + 2\dot{x} = \left(1 - \frac{(1-\mu)}{r_1^3} - \frac{\mu}{r_2^3}\right)y$$

$$\ddot{z} = -\left(\frac{(1-\mu)}{r_1^3} + \frac{\mu}{r_2^3}\right)z$$

$$r_1 = \sqrt{(x+\mu)^2 + y^2 + z^2}$$

$$r_2 = \sqrt{(x-1+\mu)^2 + y^2 + z^2}$$

$$\mu = \frac{M_{Moon}}{M_{Moon} + M_{Earth}}$$

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Results (Matlab and STK)

ISS to Earth-Moon L1

(Scenario 1)

Earth-Moon L2 to Earth-Moon L1

(Scenario 2)

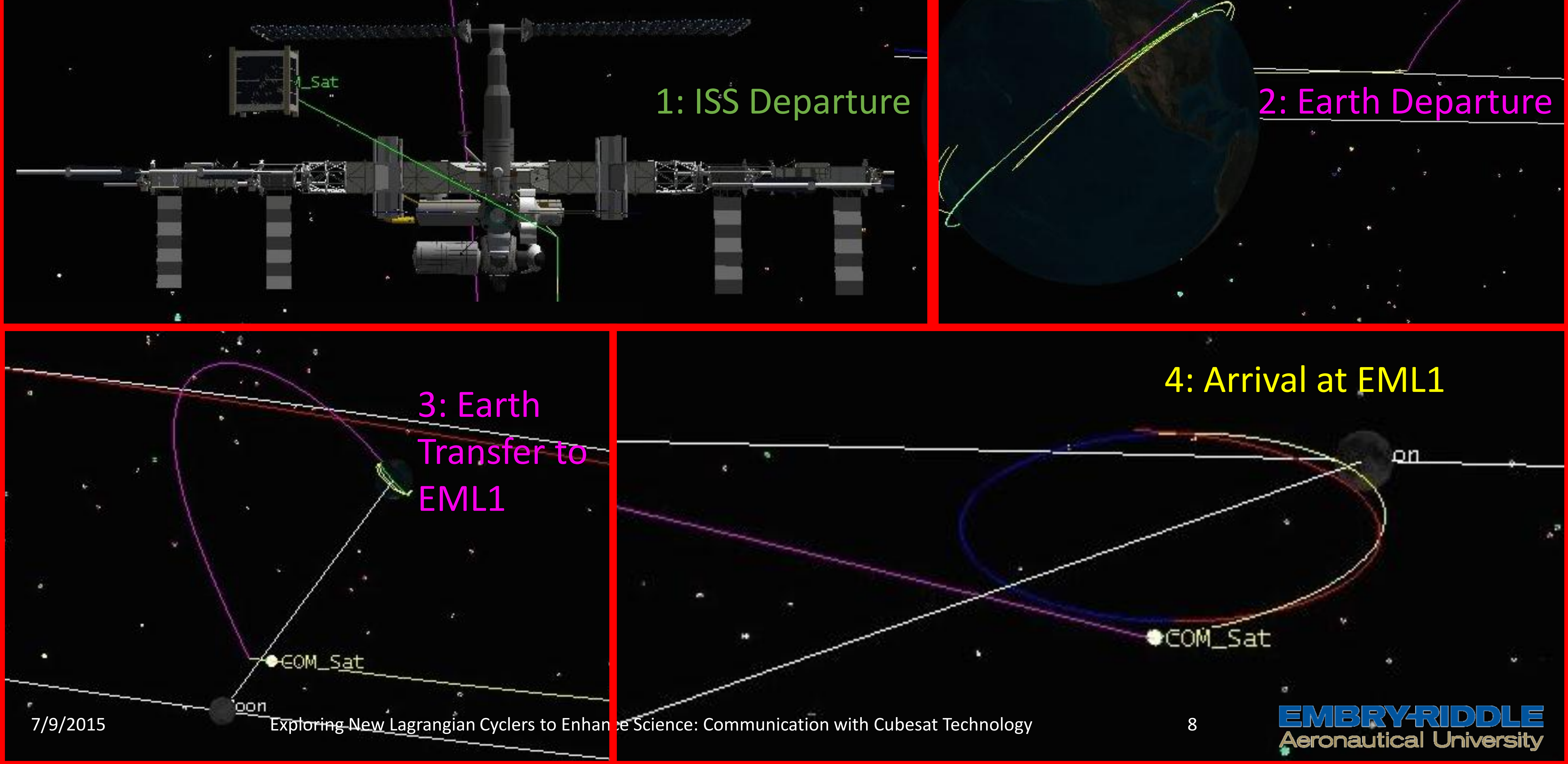
CubeSat departs ISS and does an Orbital Transfer to EML1.

CubeSat shows capability to transfer between Libration Points.

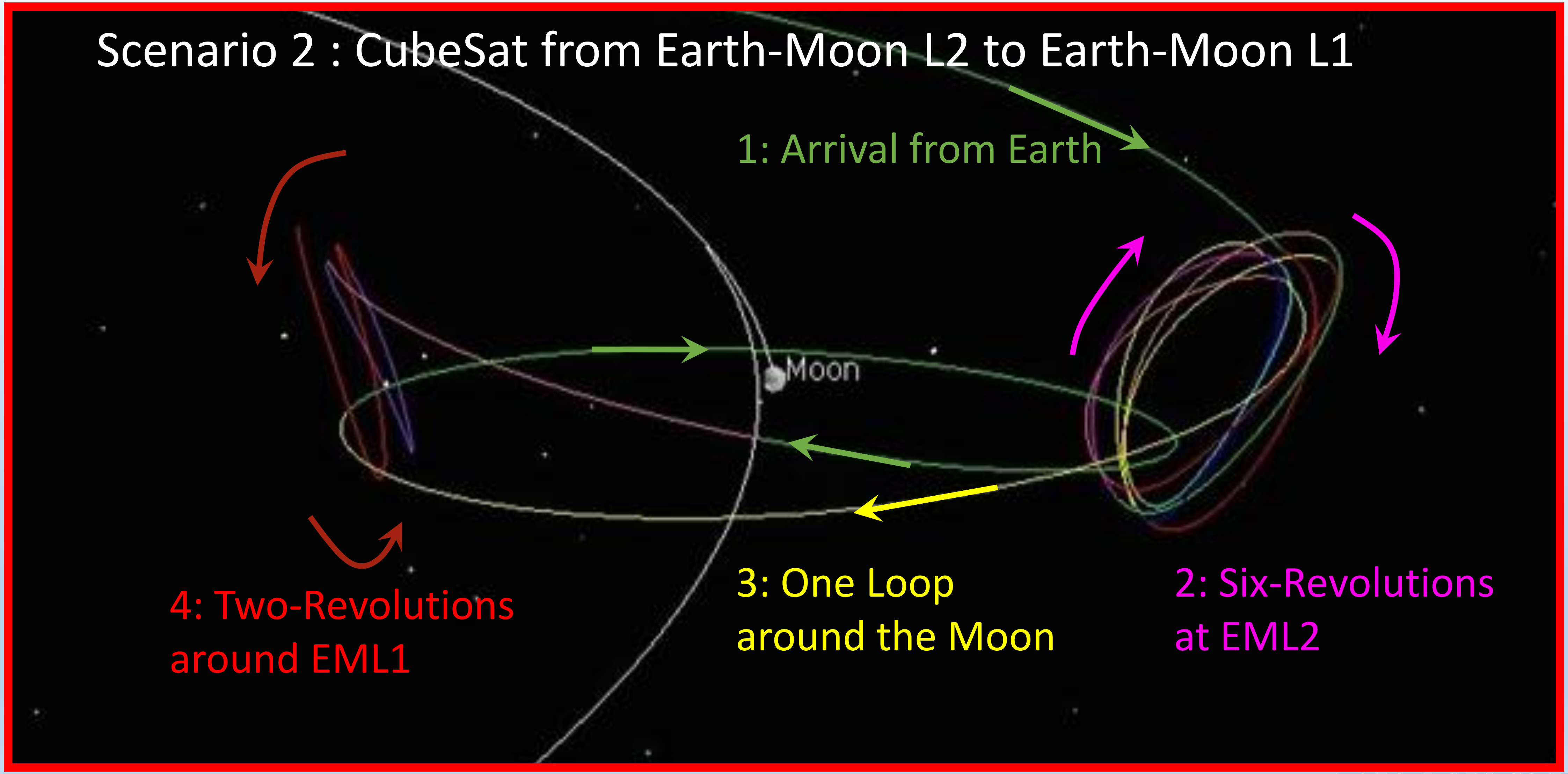
Minor stationkeeping maneuvers for both scenarios with low ΔV

Photo Credit: NASA

Scenario 1 : From ISS to Earth-Moon Lagrange Point L1 (EML1)



Results (Matlab and STK)



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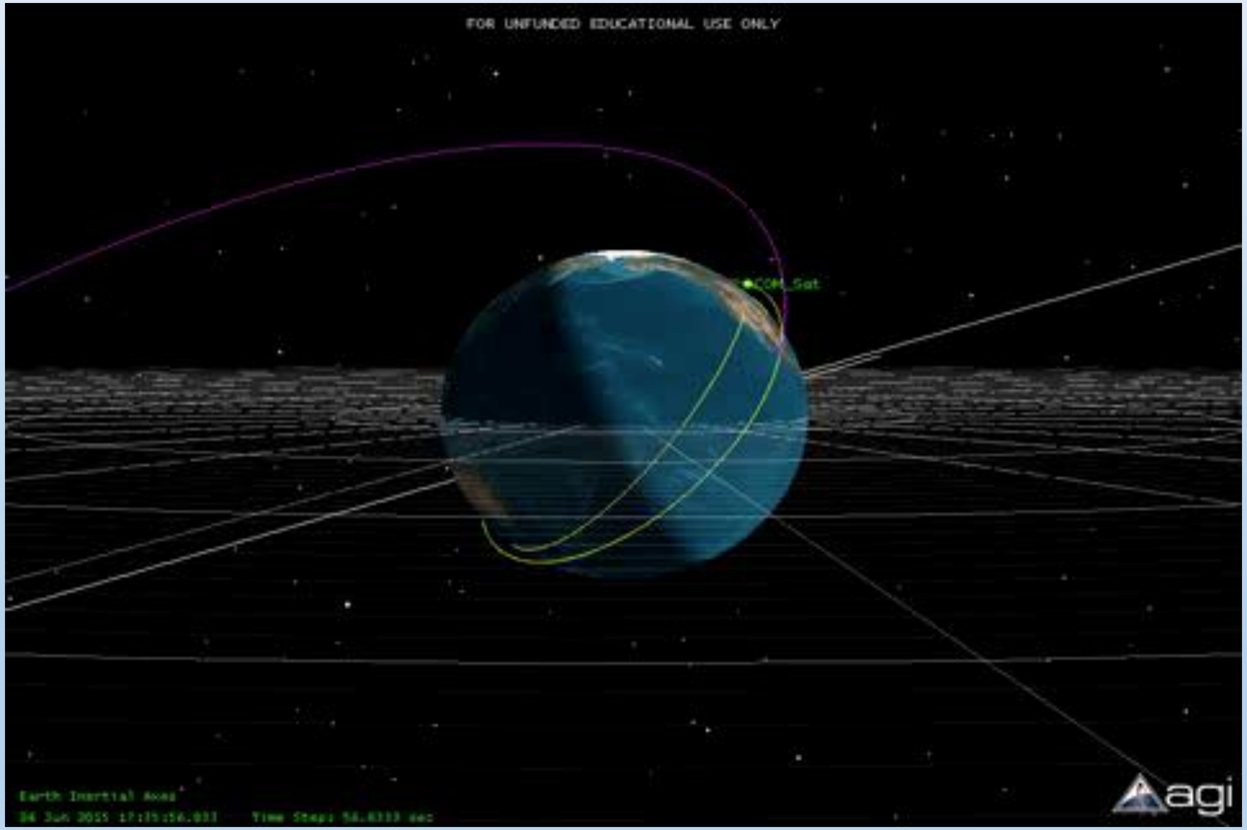
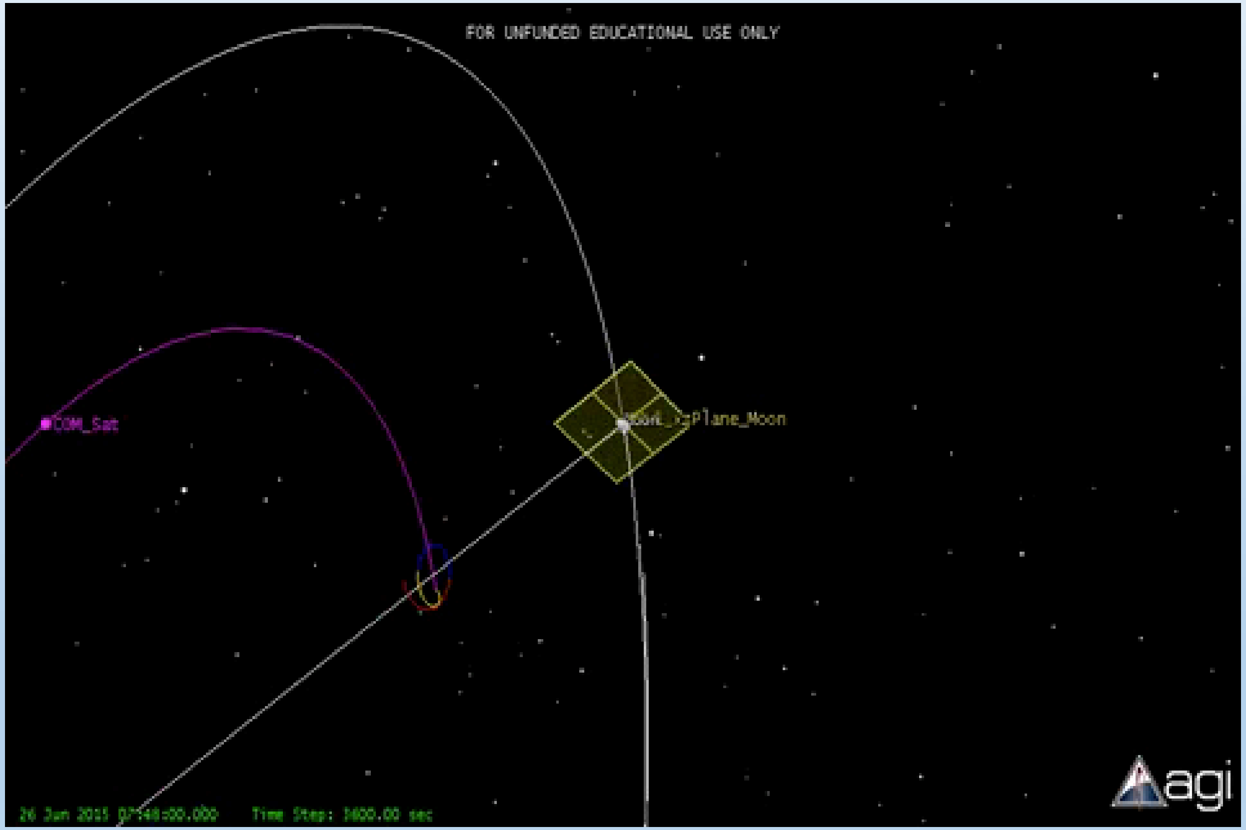
Results: STK Simulations

Scenario 1 (ISS to EML1)





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Results (Matlab and STK)

Scenario 1 (ISS to EML1)

- ISS departure ΔV = 3.120 km/s
- Time of flight = 4 days 9 hours

- EML1 (Orbit Insertion + SK) ΔV = 740 m/s
- Number of Orbits = 2
- Time in Orbit = 17 days and 7 hours

SK=Stationkeeping

Scenario 2 (EML2 to EML1)

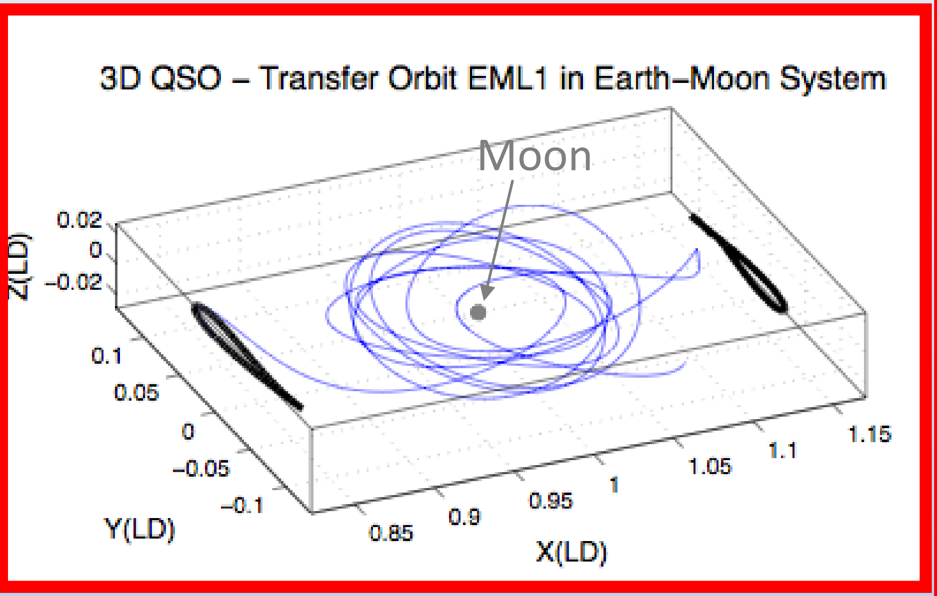
- EML2 (Orbit Insertion + SK) ΔV = 1.065 km/s
- Number of Orbits = 6
- Time in Orbit = 2 months and 11 days

- EML2 to EML1 transfer ΔV = 350 m/s
- Time of Transfer = 17 days

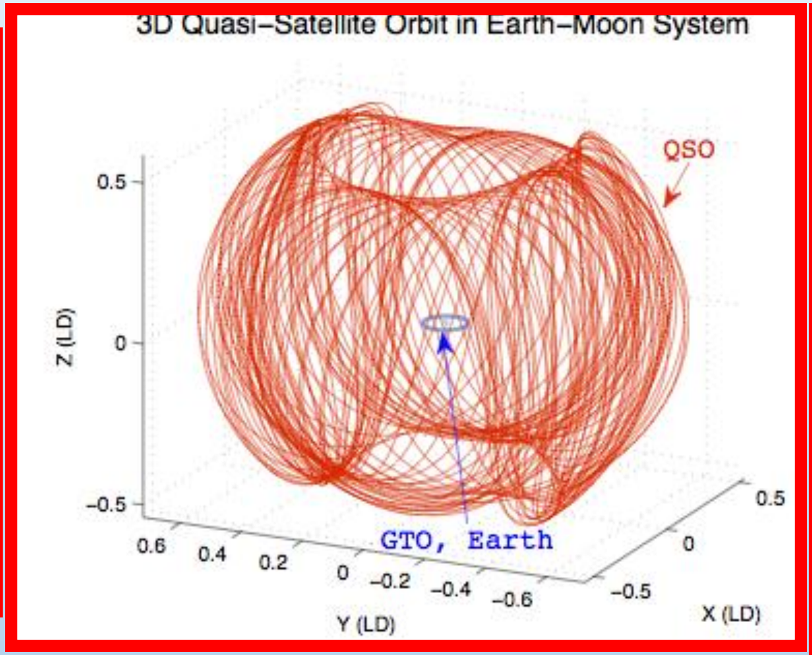
- EML1 (Orbit Insertion + SK) ΔV = 370 m/s
- Number of Orbits = 2
- Time in Orbit = 24 days

Results: Novel Cyclers

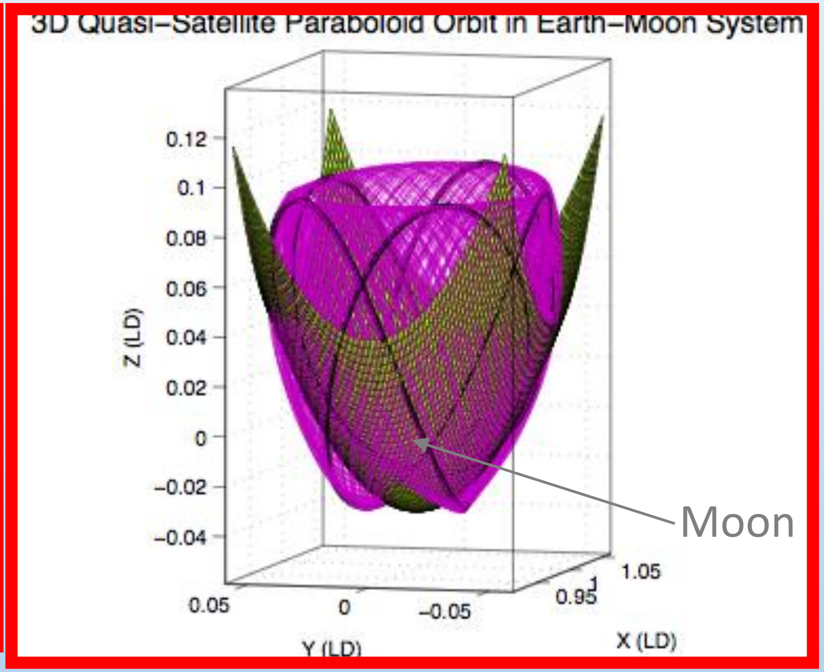
QSO between EML1 and EML2



QSO in Earth's vicinity



QSO Paraboloid



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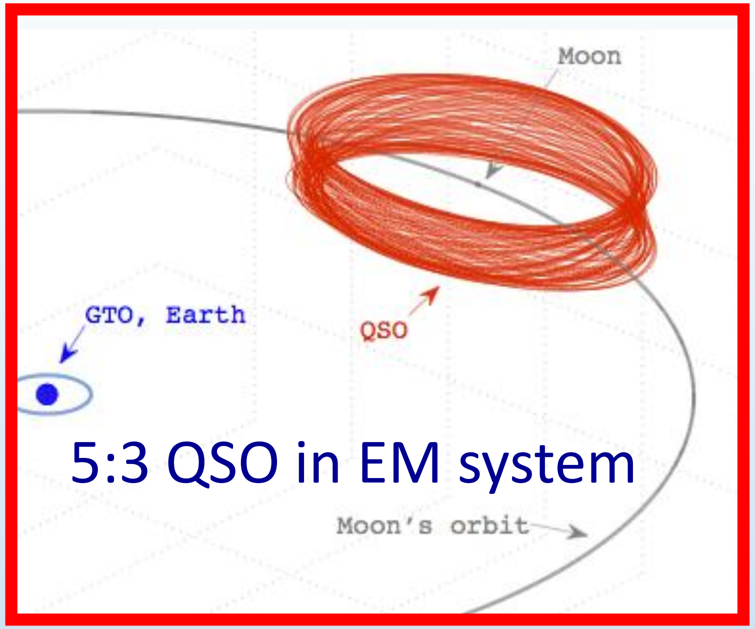
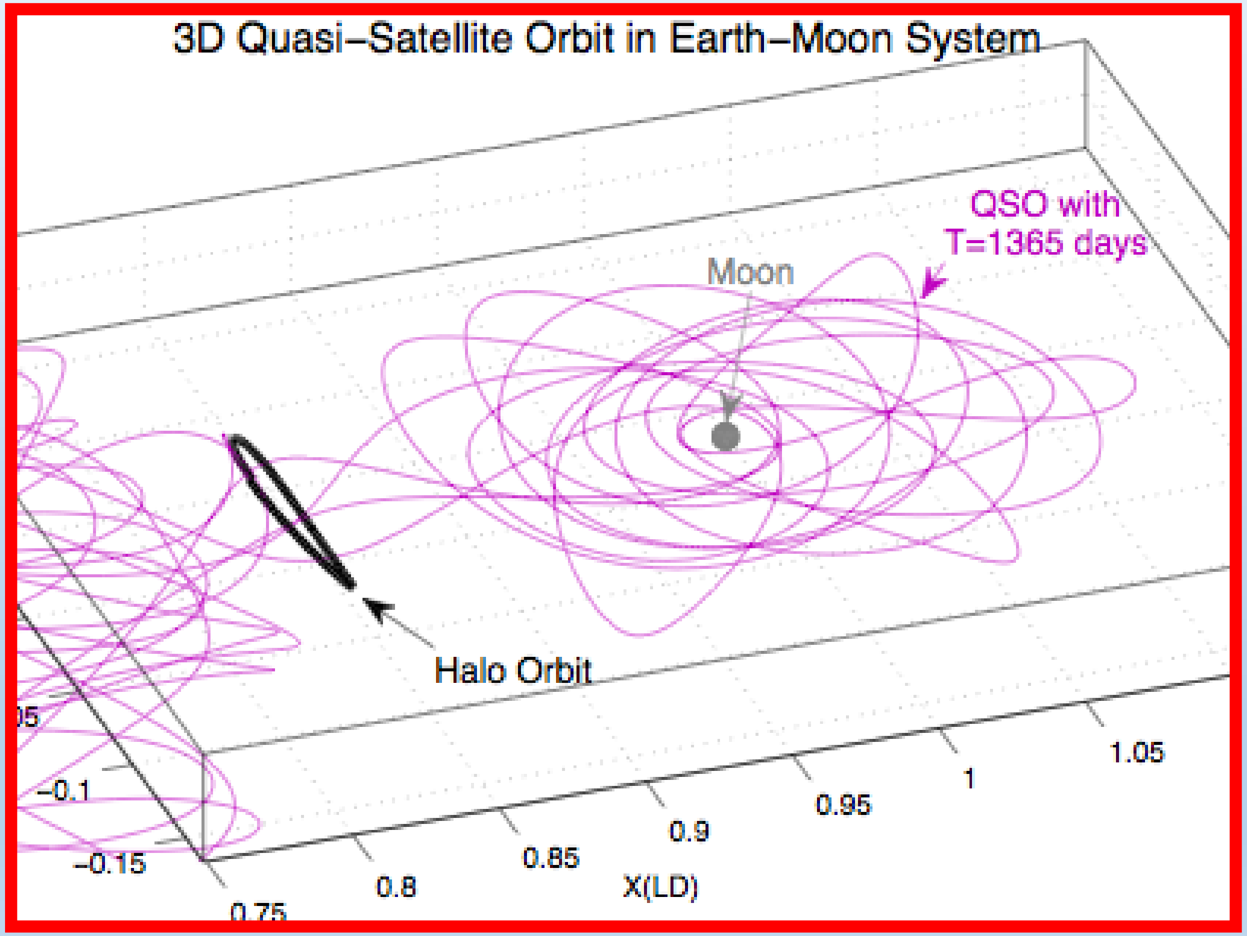
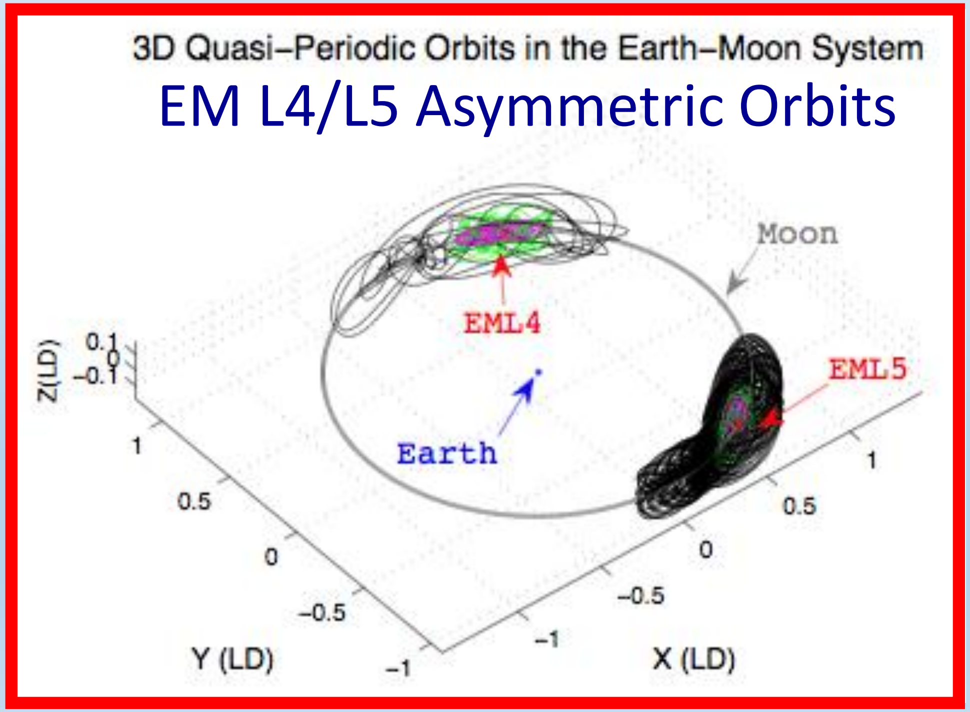
Results: Novel Cyclers

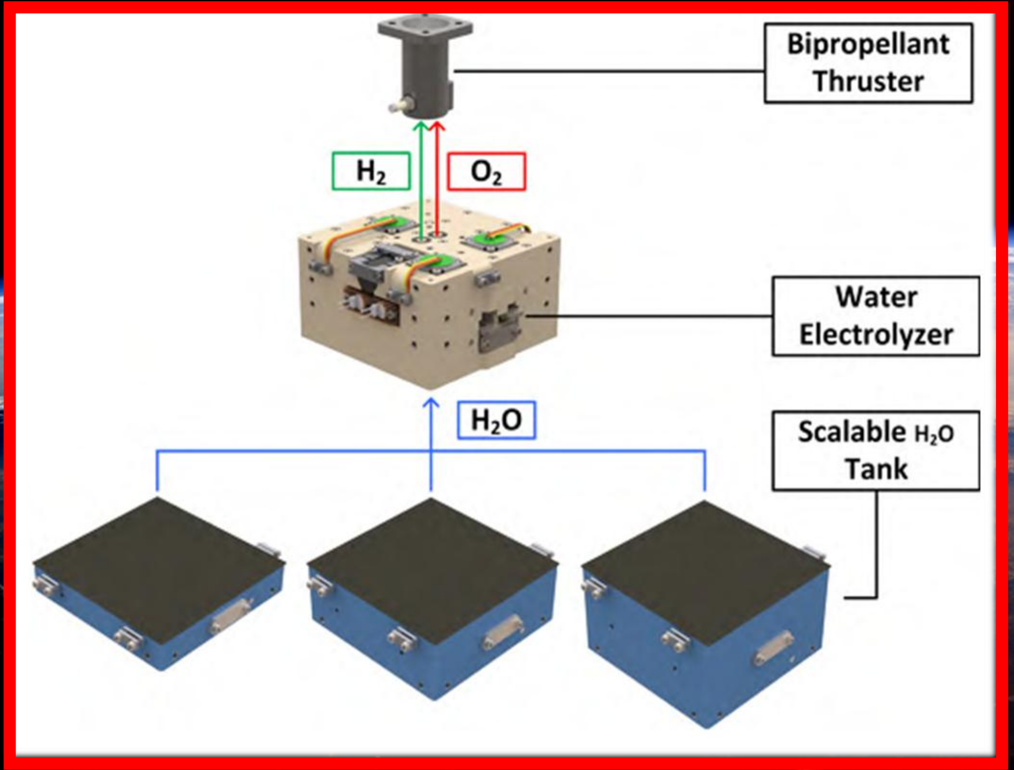


QSO going through gate EML1 connecting Earth & Moon





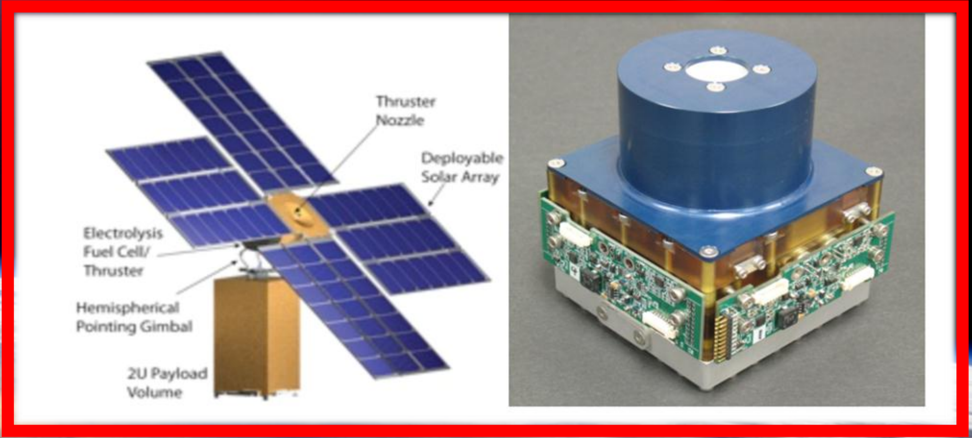
CubeSat Performance



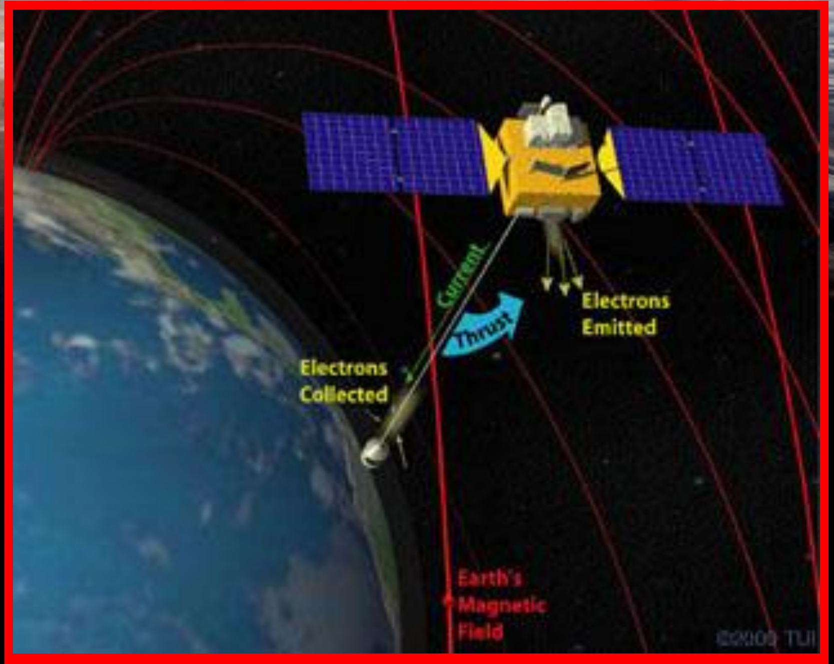
Pictures and Data courtesy of: Tethers Unlimited

HYDROS Thruster - scalable to >2km/s (Electrolysis)

PowerCube – up to 6m/s per orbit (Electrolysis)



MicroPET – raising propellantless system (Electrodynamic Tethers)



Sun-Earth Day 2008: Space Weather Around the World
sunearthday.nasa.gov

Future Work: Applications

- Science and Communication
  - Gravitational Field Mapping
  - Cislunar or Interplanetary CubeSat
  - Space Weather Monitoring
  - Low Data Rate communications with fleet of CubeSat
  - Technology testing for Mars and its Moons (AIAA-2014-4349)

Photo Credit: NASA (INSPIRE) CubeSat project

Future Work: Applications

Orbital Debris Monitoring

- ISS Departure (400km) to Low Earth Orbit (725km)
    - Debris Resistive/Acoustic Grid Orbital Navy Sensor (DRAGONS)
- Better understanding of MicroMeteroid and Orbital Debris (MMOD)
- Impact avoidance for ISS and reduction of collision avoidance maneuvers.

Picture credit: Lynx

Orbit Maintenance

- CubeSat deployment from ISS (NanoRacks); JEM (Cyclops launcher), Orbital (Jupiter/Exoliner) and Suborbital flight vehicle (example: Lynx Mark III) deploying the CubeSat from its dorsal pod using a dual stage rocket.
- Satellite Stationkeeping, safe deorbit, repair, maintenance.

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Thank you for your attention

Questions?

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Photo Credit: ESA

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