Dynamic Control of a CubeSat Attitude and Orbit Control System (AOCS) with Propulsion for Deep-Space Missions

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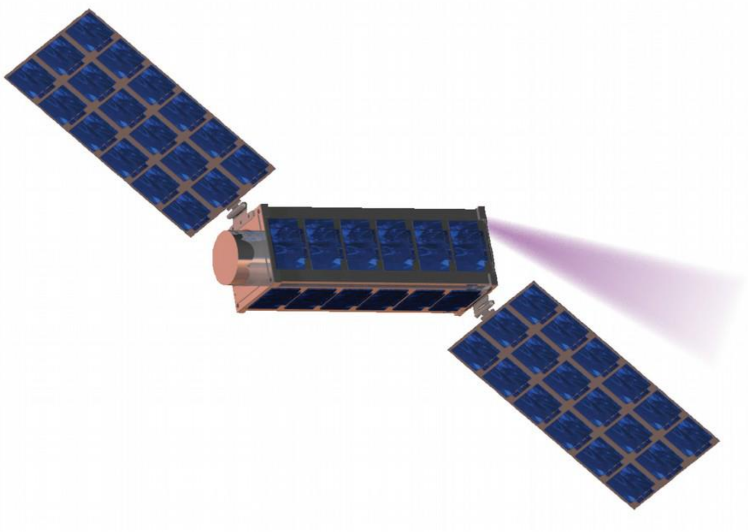
Outline

- Mission concept
- Deep-space mission
- Thruster
- AOCS model
- Simulation
- Conclusion



Mission concept

Interplanetary mission

0 Earth at launch

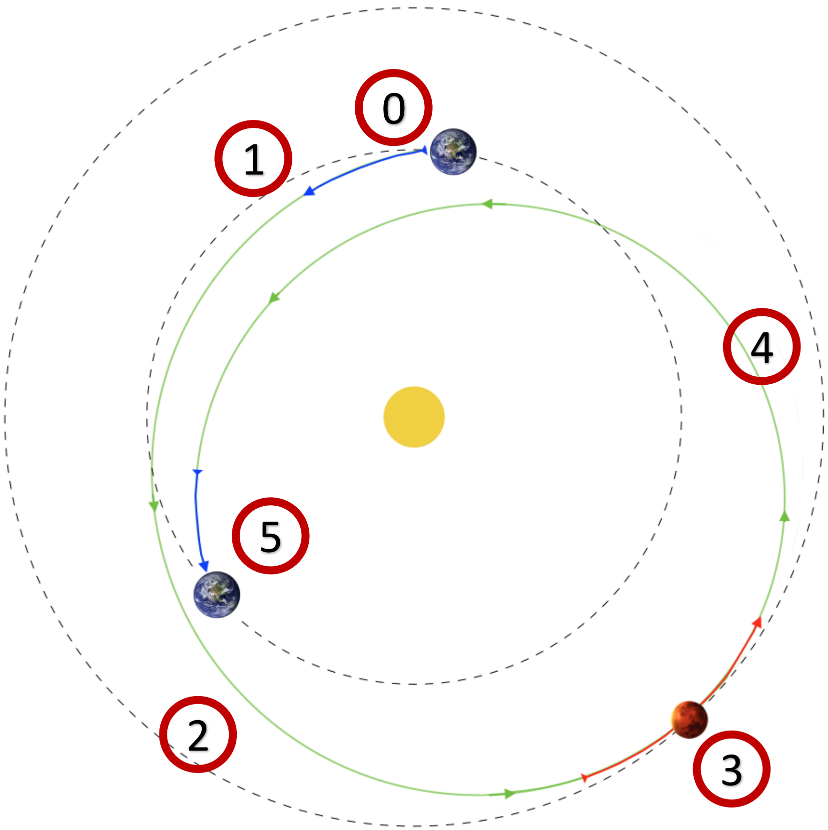
1 Deployment after deploy from mothercraft

2 Earth-to-Mars science and navigation

3 Mars fly-by: first datalink

4 Marth-to-Earth science and navigation

5 End of Mission : Final datalink

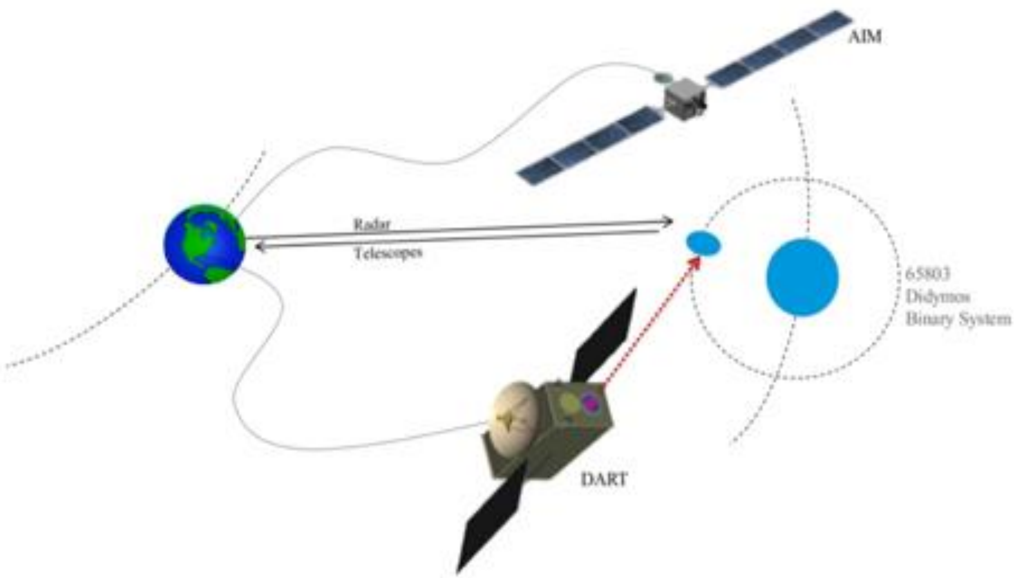


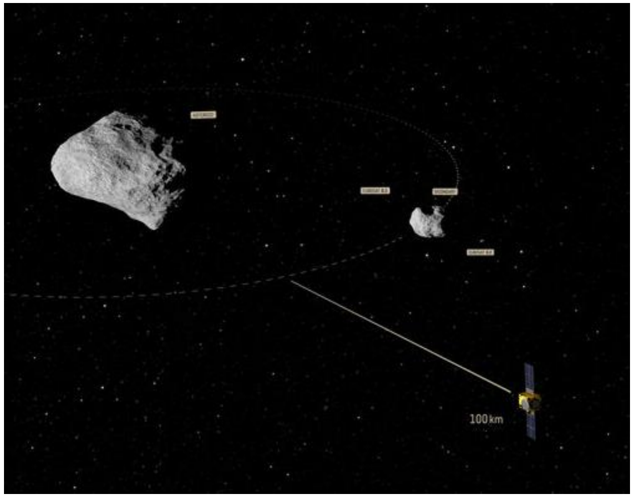
(trajectory inspired by Dennis Tito for 2018)

Mission concept

Orbiting an asteroid

1. Released in situ by mothercraft
2. Navigation mode
3. Science mode
4. Navigation mode
5. TT&C to mothercraft

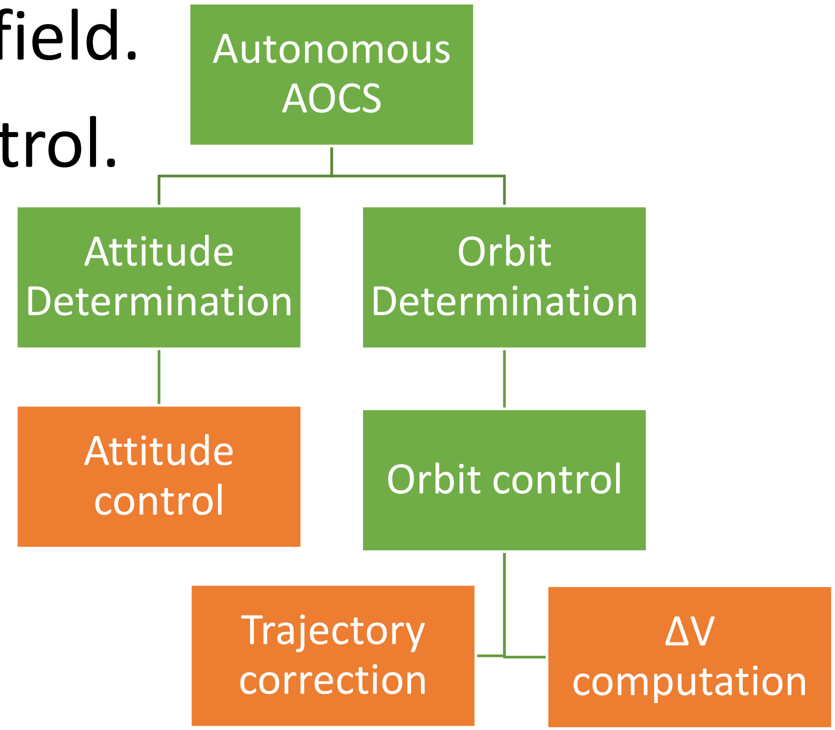




Models © ESA (Galvez/Carnelli)

Deep-space mission

- Limited experience and data.
- Lack of structured magnetic field.
- Orbit determination and control.
- Limited actuators and sensors capabilities.
- Propulsion system needed.
- Communication issue.

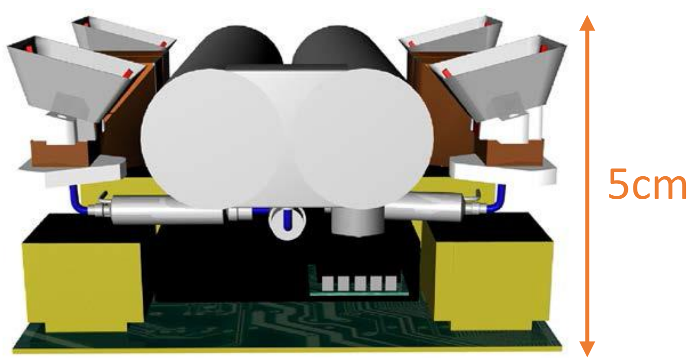


Scope of this work

Work done by other team member

Thruster- L-μPPT

- TRL=4
- Liquid Micro Pulsed Plasma Thruster
- 4-off-axis-thruster configuration
- Space qualified liquid propellant
- Use on both attitude control and trajectory correction.



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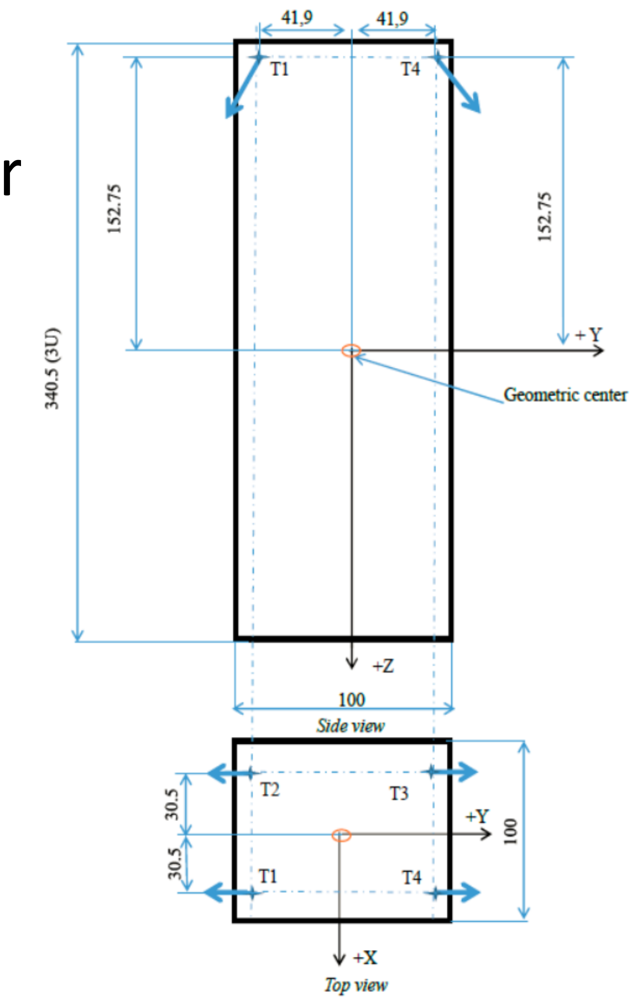

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Thruster- Dynamics

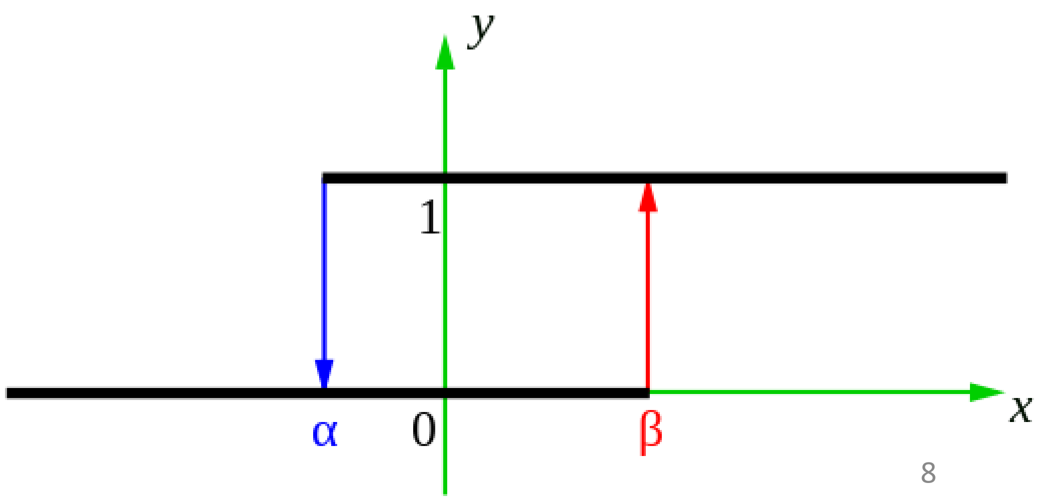
- Thruster torque output T_c can be expressed as:

$$T_c = B_a u$$
$$u = [\ F_1\ F_2\ F_3\ F_4]^T$$

- T_c is calculated by the control law.
- $B_a$contains information about moment arms and thrust direction for each thruster.
- Solve u to get which thruster should active.
- Schmitt trigger has been implemented into the actuator controller.

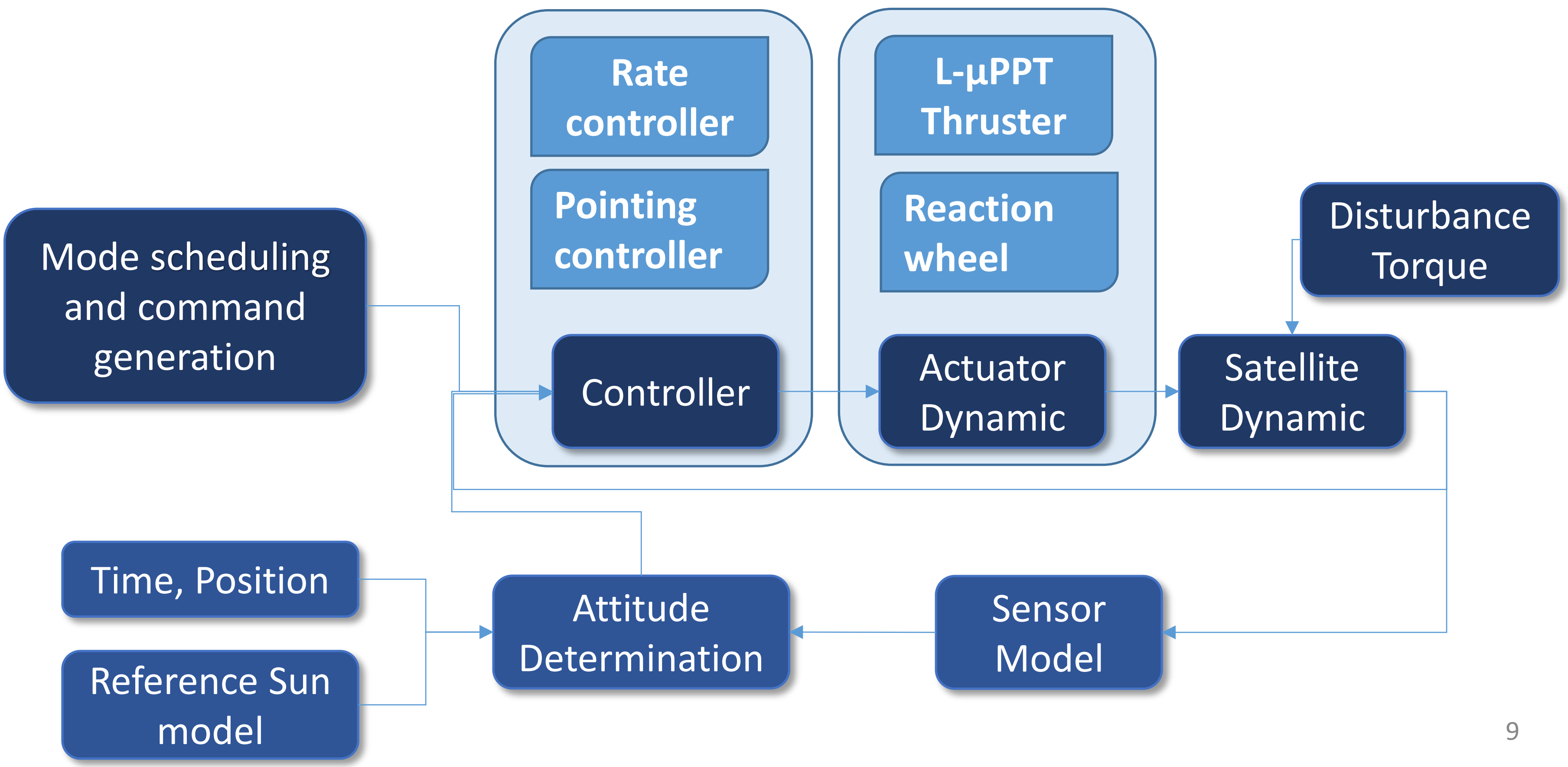
Thruster- Schmitt Trigger

- Relay with deadband/hysteresis.
- Control frequency for L-μPPT is limited to 1Hz.
- Advantage
  - Effective in term of fuel used.
  - Prevent the thruster from sensor noise impact.
  - Flexible structure.
- Disadvantage
  - Accuracy.



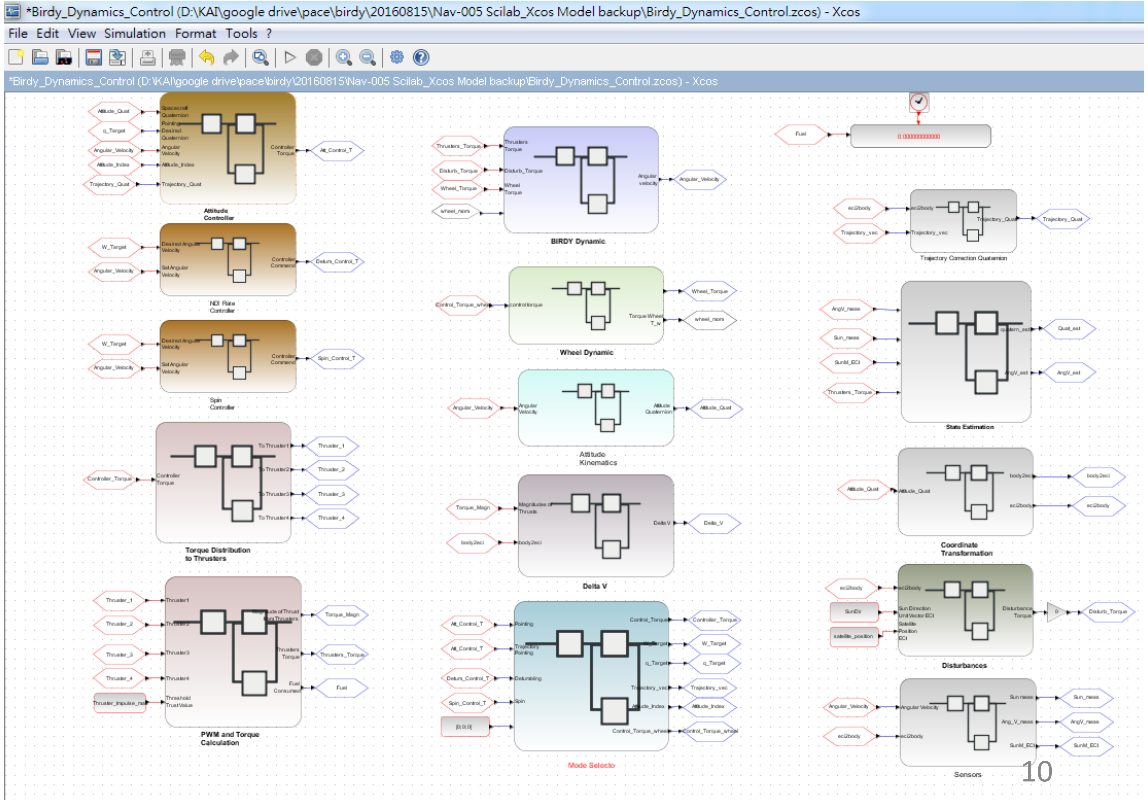
AOCS Model

- AOCS Simulation Tool Configuration



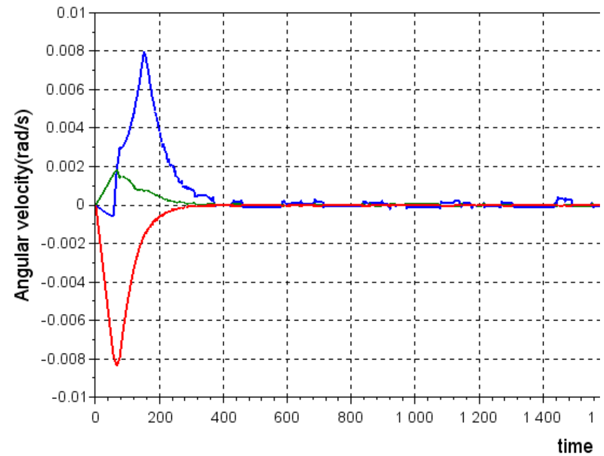
AOCS Model

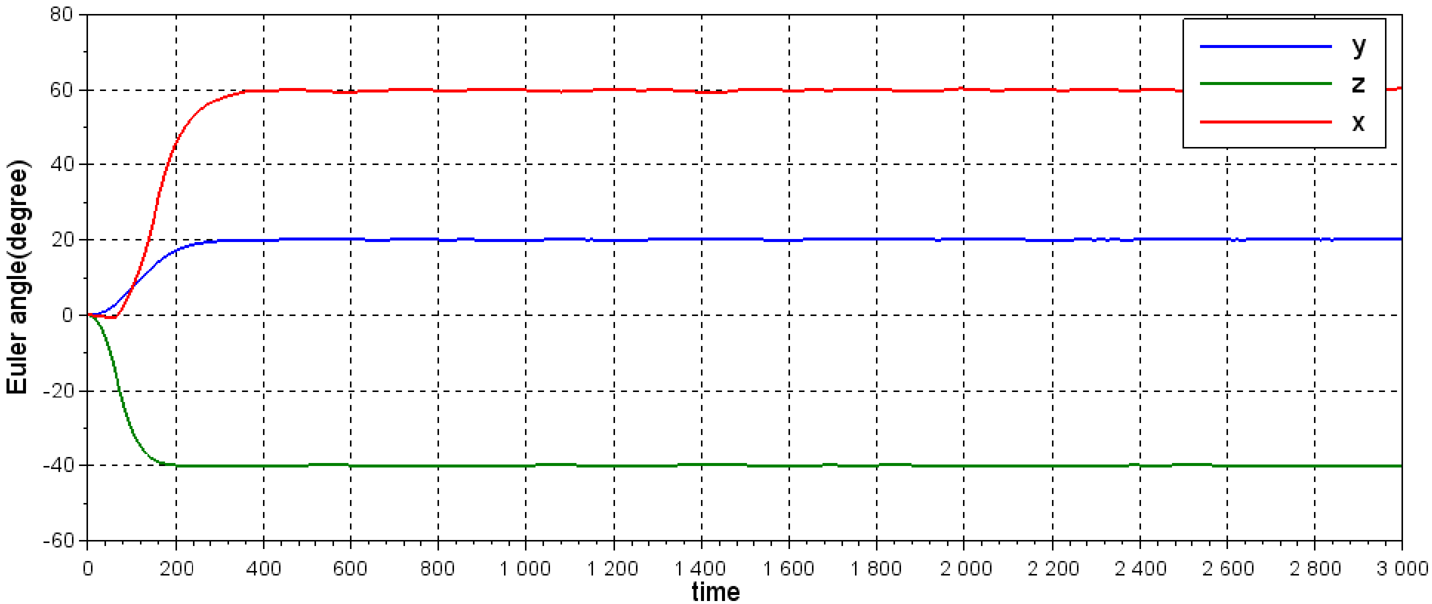
- Simulation Tool on Scilab/Xcos.
- Free and open source software for numerical computation.



Simulation-Pointing Simulation

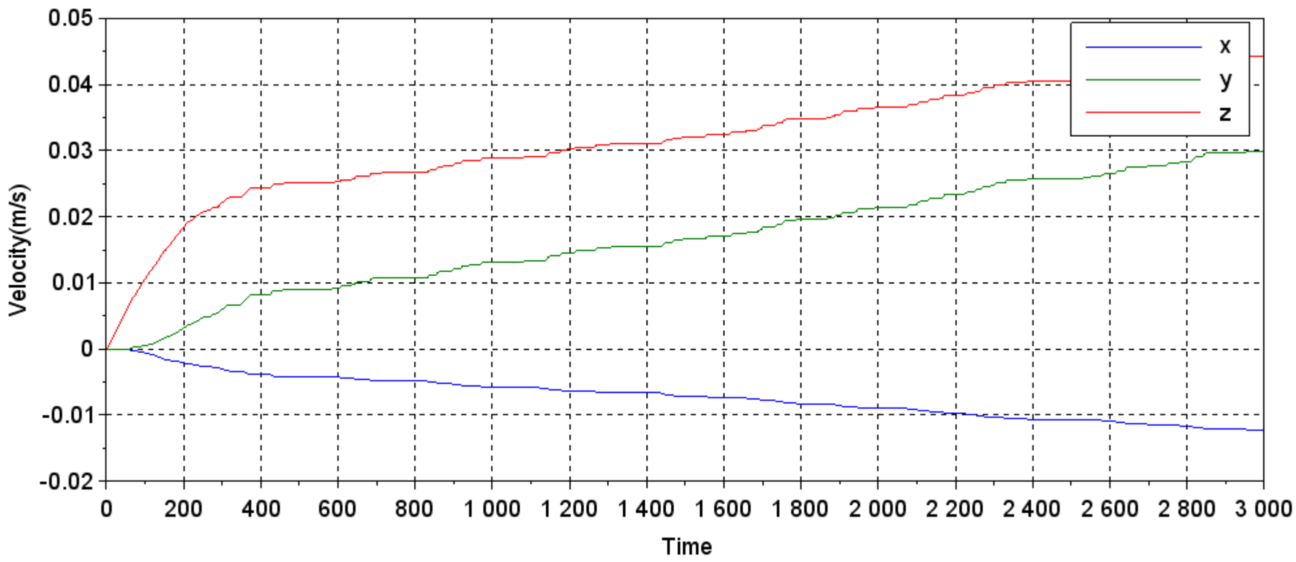
- Desired Euler angle: [60,20,-40]
- Initial Euler angle :[0, 0, 0]
- L-μPPT can control the attitude to the desired pointing angle





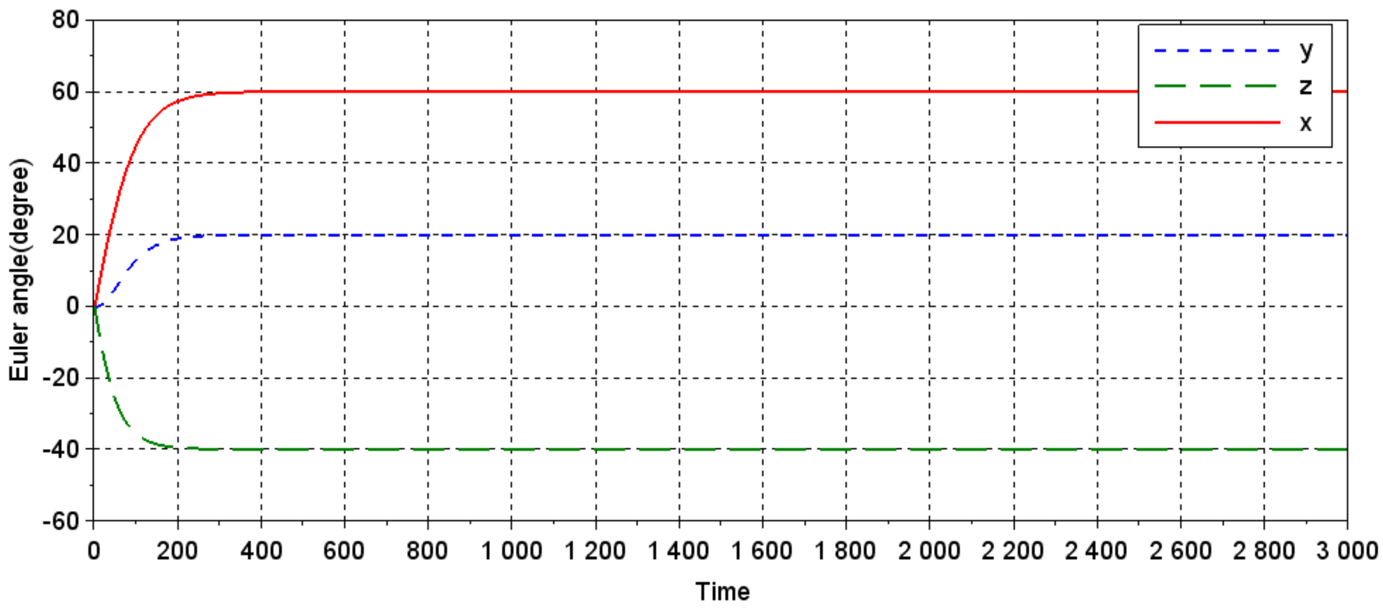
Simulation-Pointing Simulation

- Use L-μPPT to control the attitude, the induced velocity impact should be considered.



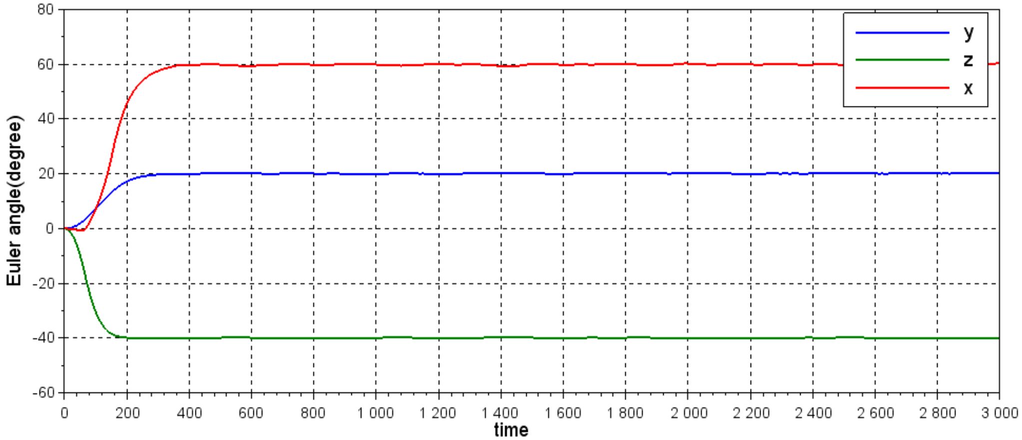
Simulation-Pointing Simulation

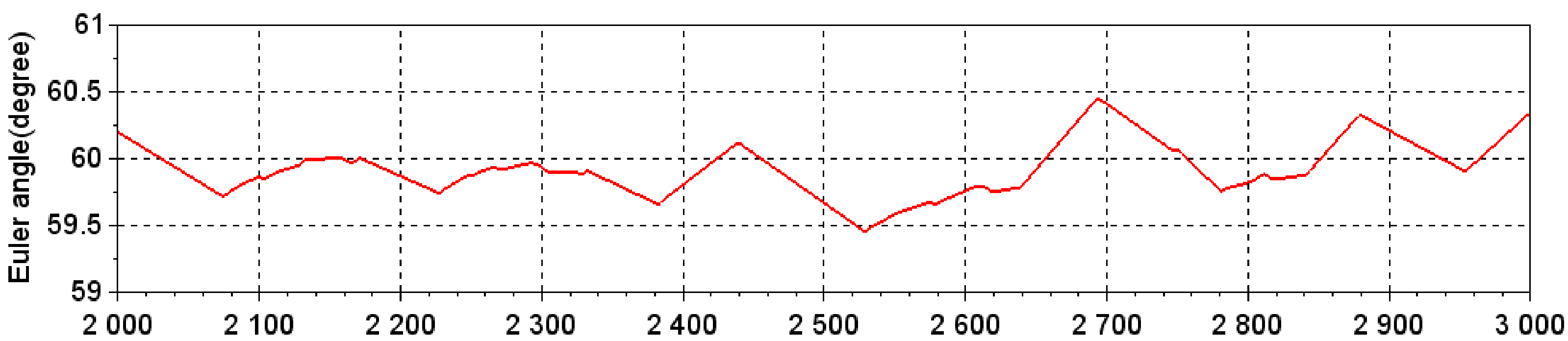
- Pointing simulation with 3-wheel actuator
- Use wheel to control attitude so as to avoid the effect due to induced velocity.



Simulation- Schmitt trigger

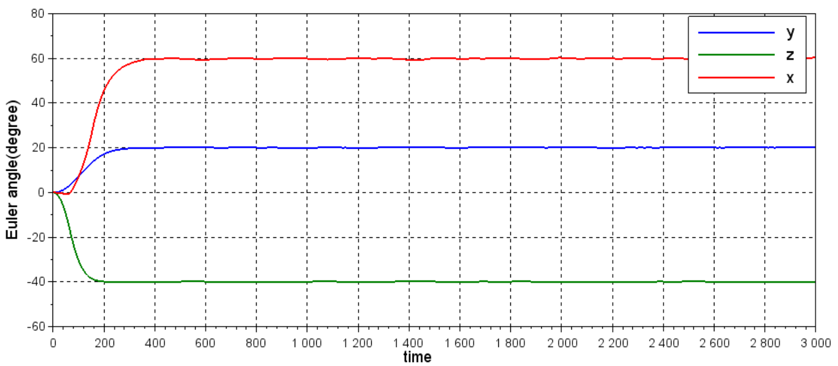
- Fuel consumption is 0.01011g

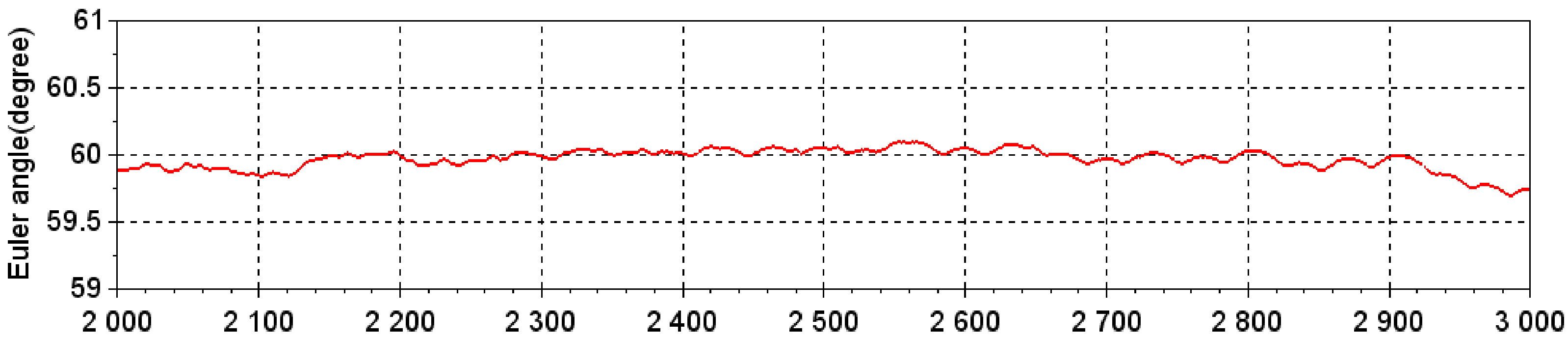




Simulation- Schmitt trigger

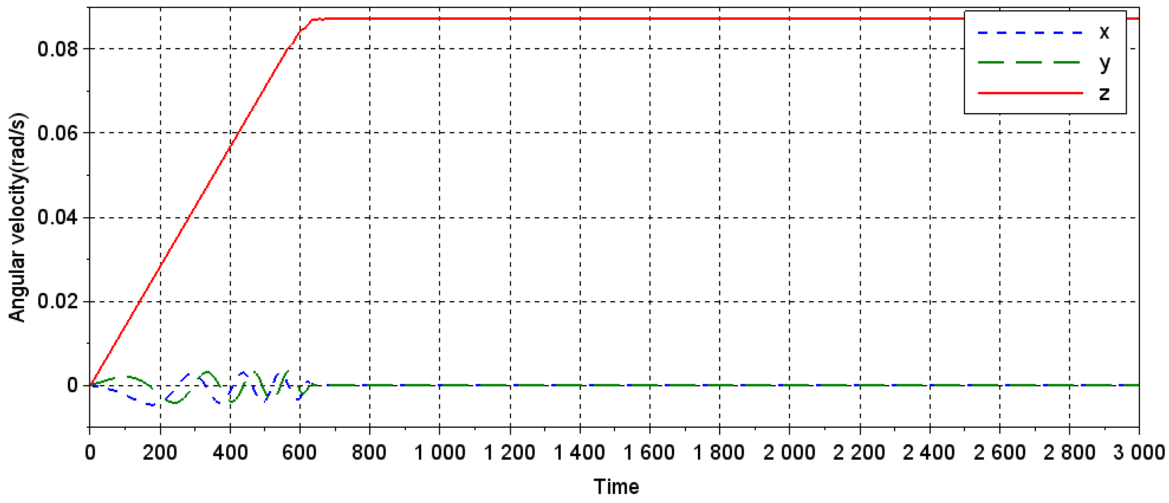
- Fuel consumption is 0.04459g
- Effective in term of fuel used





Simulation-Spin Simulation

- Spin along a specific axis using the L-μPPT
- The spin mode is important for regulating the heat on the surface of the satellite.
- Also for spin stability.
- Desired Angular velocity [0,0,0.0872](rad/s)



Conclusion

- Preliminary analysis of deep space mission's AOCS has been presented.
  - L-μPPT is able to control satellite attitude.
  - Induced velocity should be considered.
  - Schmitt trigger can improve the effectiveness of fuel consumption.
- Functional analysis approach
  - General to fit different interplanetary missions or asteroid orbiting.