Gaia Attitude Model (GAM)

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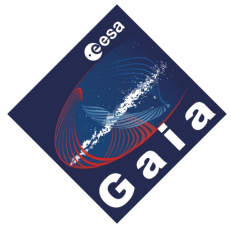

[1] Leiden Observatory
[2] ZARM, Bremen
[3] IoA, Cambridge

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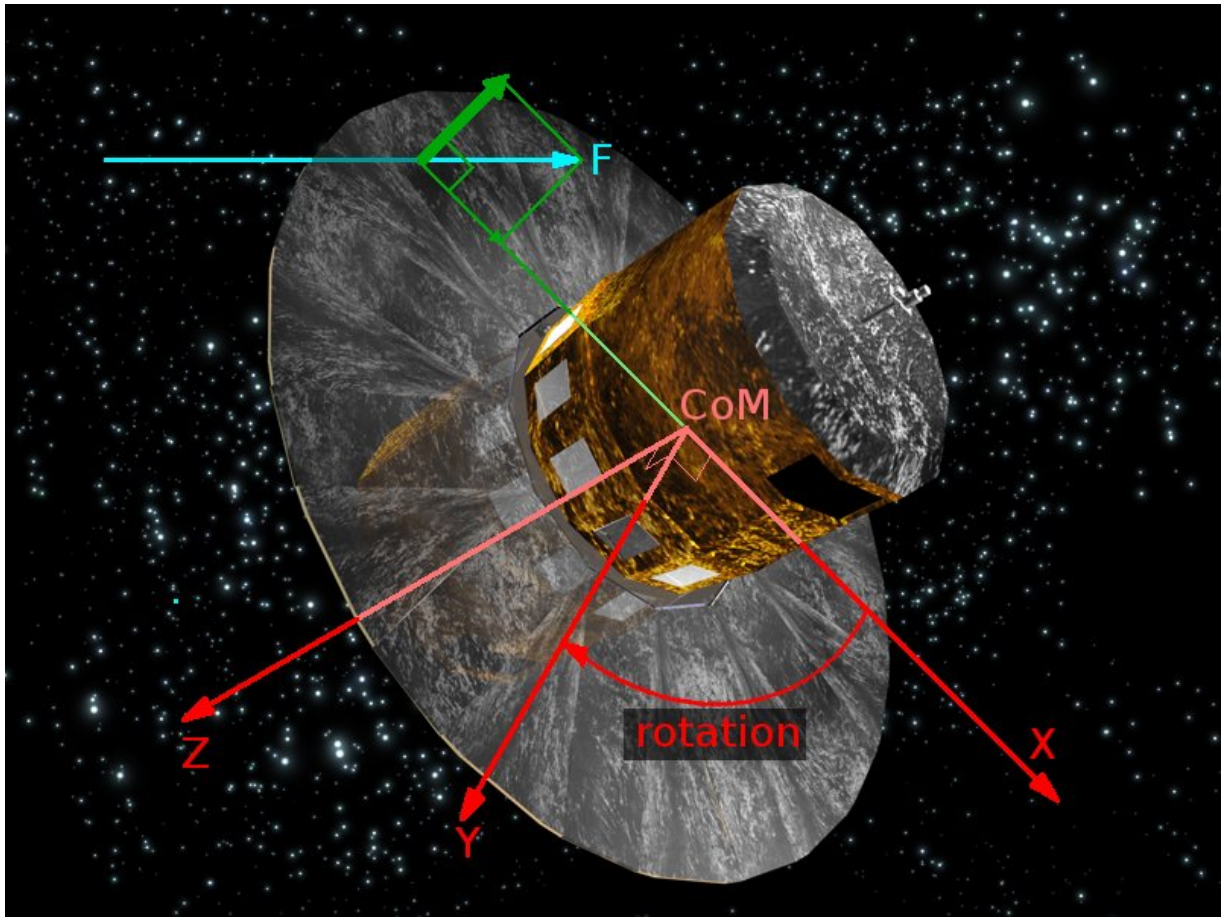
What is GAM?

Aim: create a *physical* model of Gaia and study the satellite attitude

GAM output will replace current GASS (GAia System Simulator) attitude



Why GAM?

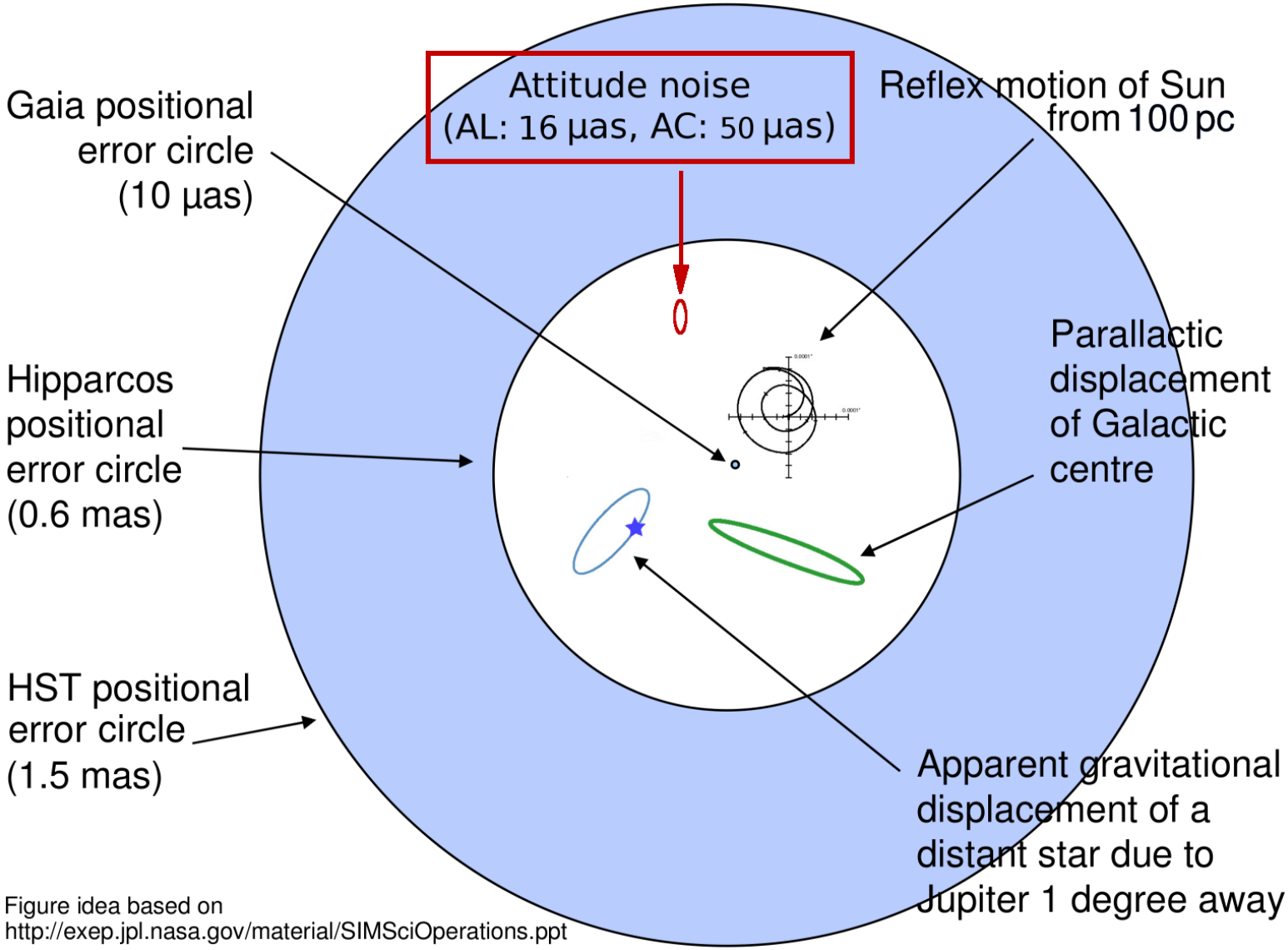
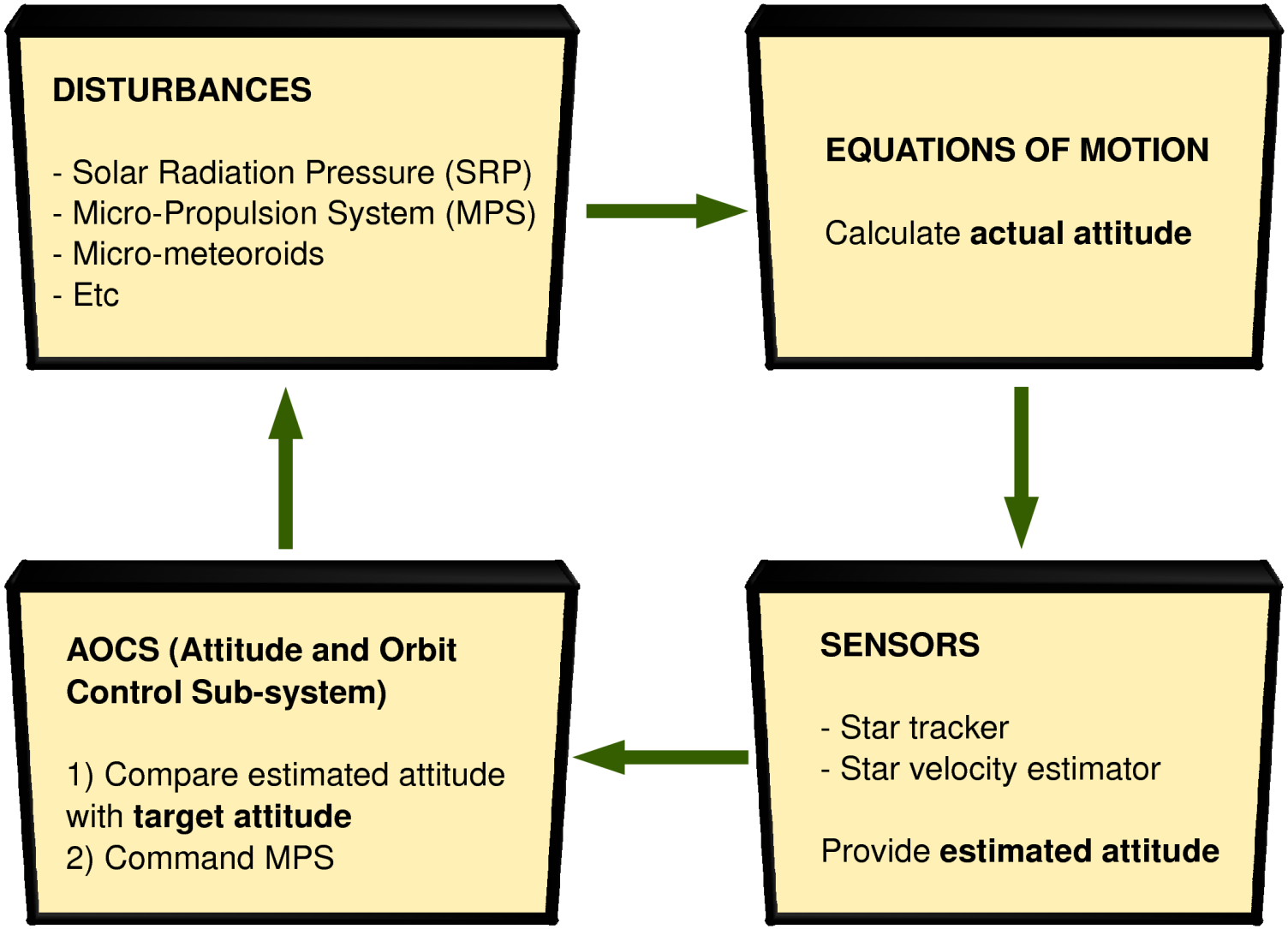


Figure idea based on
http://exep.jpl.nasa.gov/material/SIMSciOperations.ppt

Main Structure of GAM



Model Interface

- Input:
  - Initial conditions
  - Selection of available disturbances on the attitude
  - Reference Scanning Law (spin axis and Sun position)
- Output:
  - Actual and estimated state
  - AOCS (Attitude and Orbit Control Sub-system) actions

AOCS

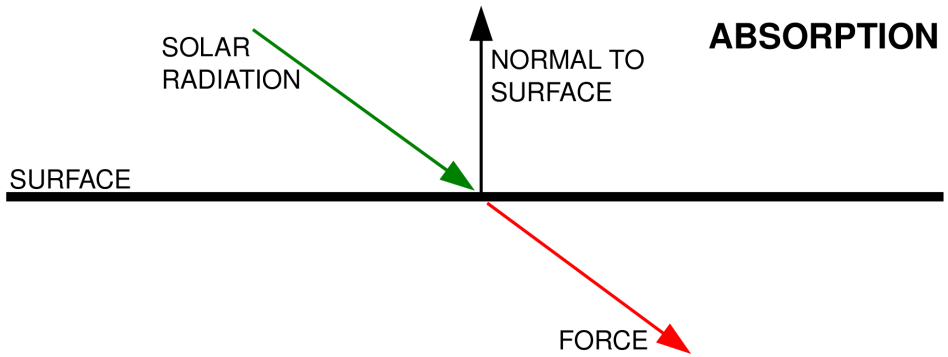
1. Get **estimated attitude** from sensors
2. Compare with the **target attitude** (Reference Scanning Law)
3. Calculate requested torque and command MPS (Micro-Propulsion System)

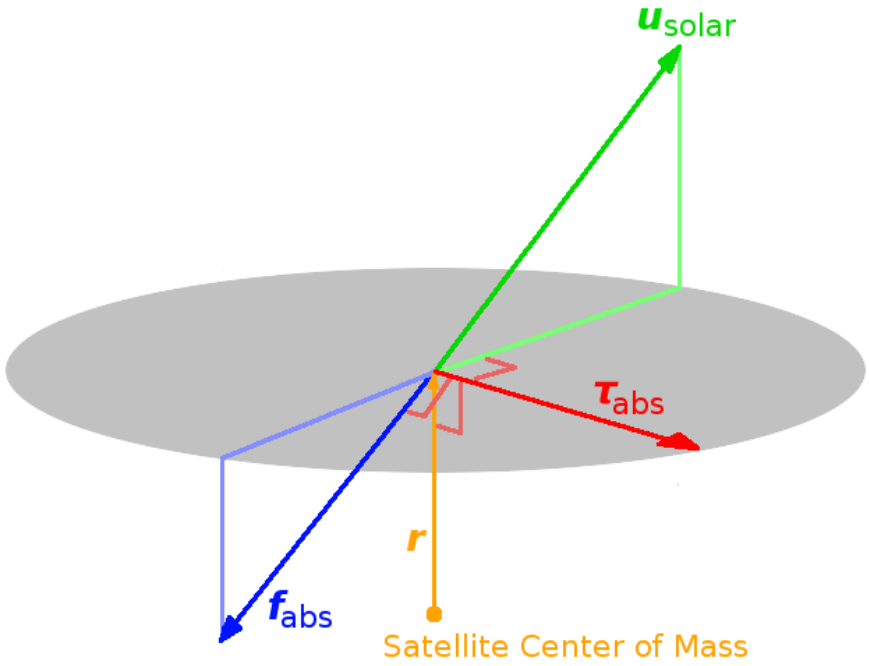
Disturbances on the Attitude

- Solar radiation pressure
- Micro-meteoroids
- Clanks (discontinuities in attitude while angular rate does not change, very unknown)
- Thermal IR emission from Gaia surface
- Micro-Propulsion System (MPS)
- And maybe others in the future

Disturbances: Solar Radiation

- Sun-shield: mesh of triangles
- 3 optical effects: absorption, specular reflection, diffuse reflection
- Total torque $\simeq 130\,\mu\mathrm{Nm}$

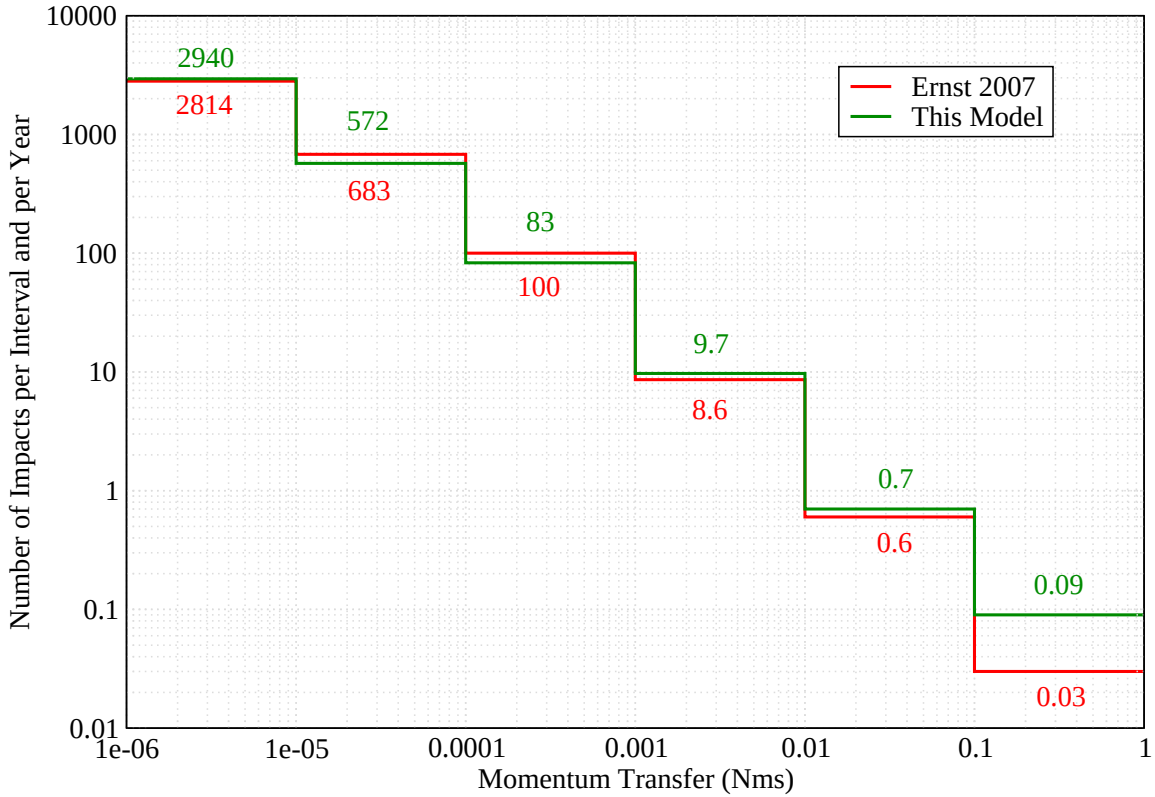




Disturbances: Micro-Meteoroids

Big impacts make AOCS change mode

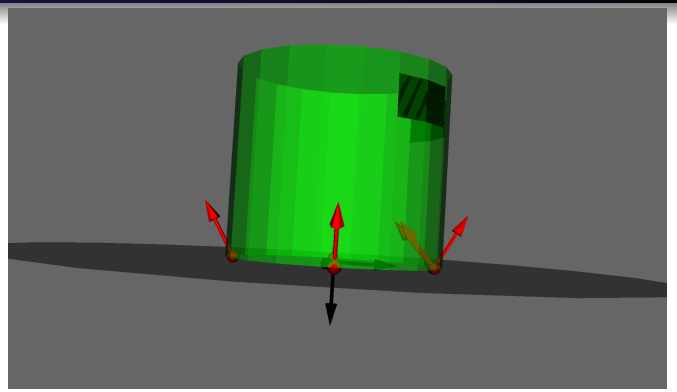
Small impacts not detected on-board, but **degrade attitude reconstruction**

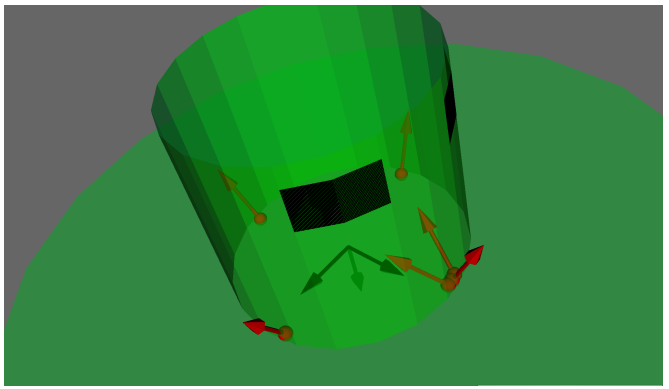


Ernst (2007) model

Disturbances: Micro-Propulsion System

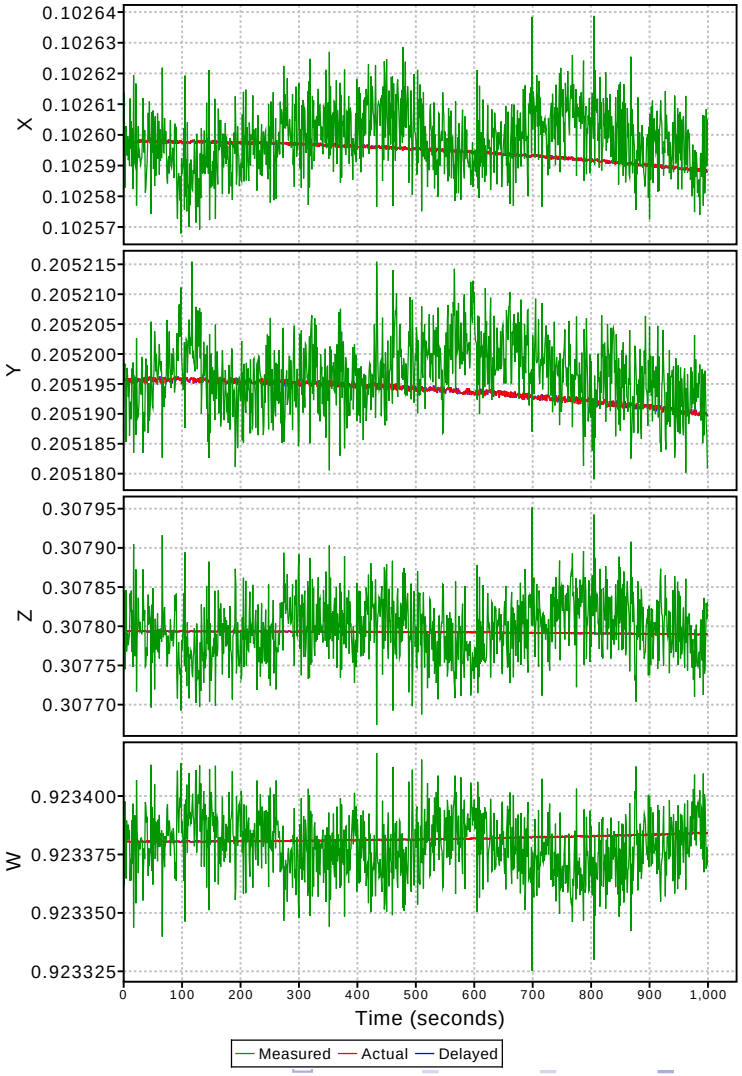
- Input: AOCS torque demand
- 6 cold-gas thrusters
- Considered disturbance because of its performances (characteristic noise, quantization, etc)
- Challenging design (force $\sim \mu$Newtons!), concerns about noise $\Rightarrow$ **Important point to simulate**





Sensors

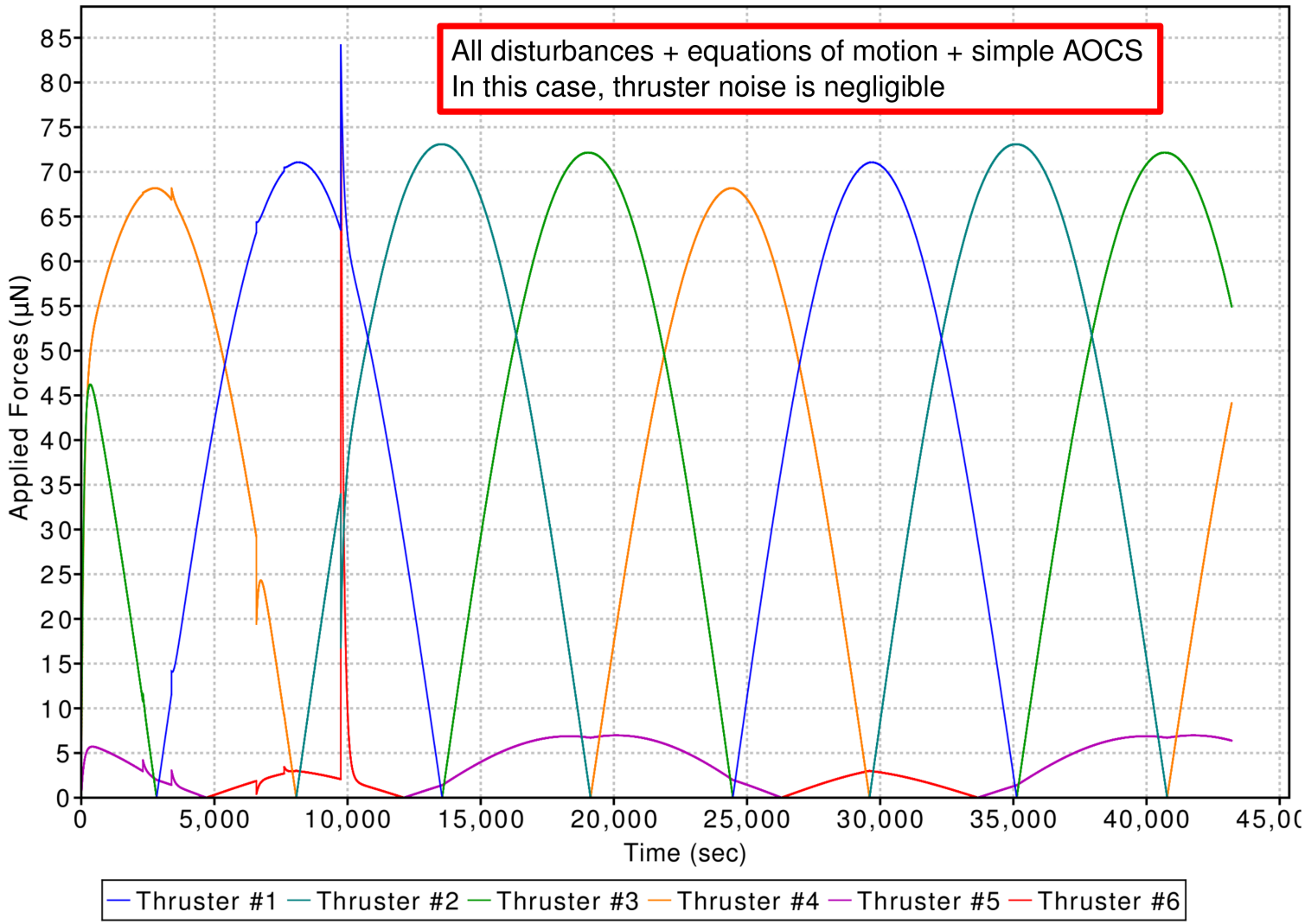
- Two implemented sensors:
  - Star tracker
  - Angular rate
- Realistic characteristics: noise, delays, etc
- Plot on the right: example about star tracker. Quaternion (**measured** and **actual**) vs time



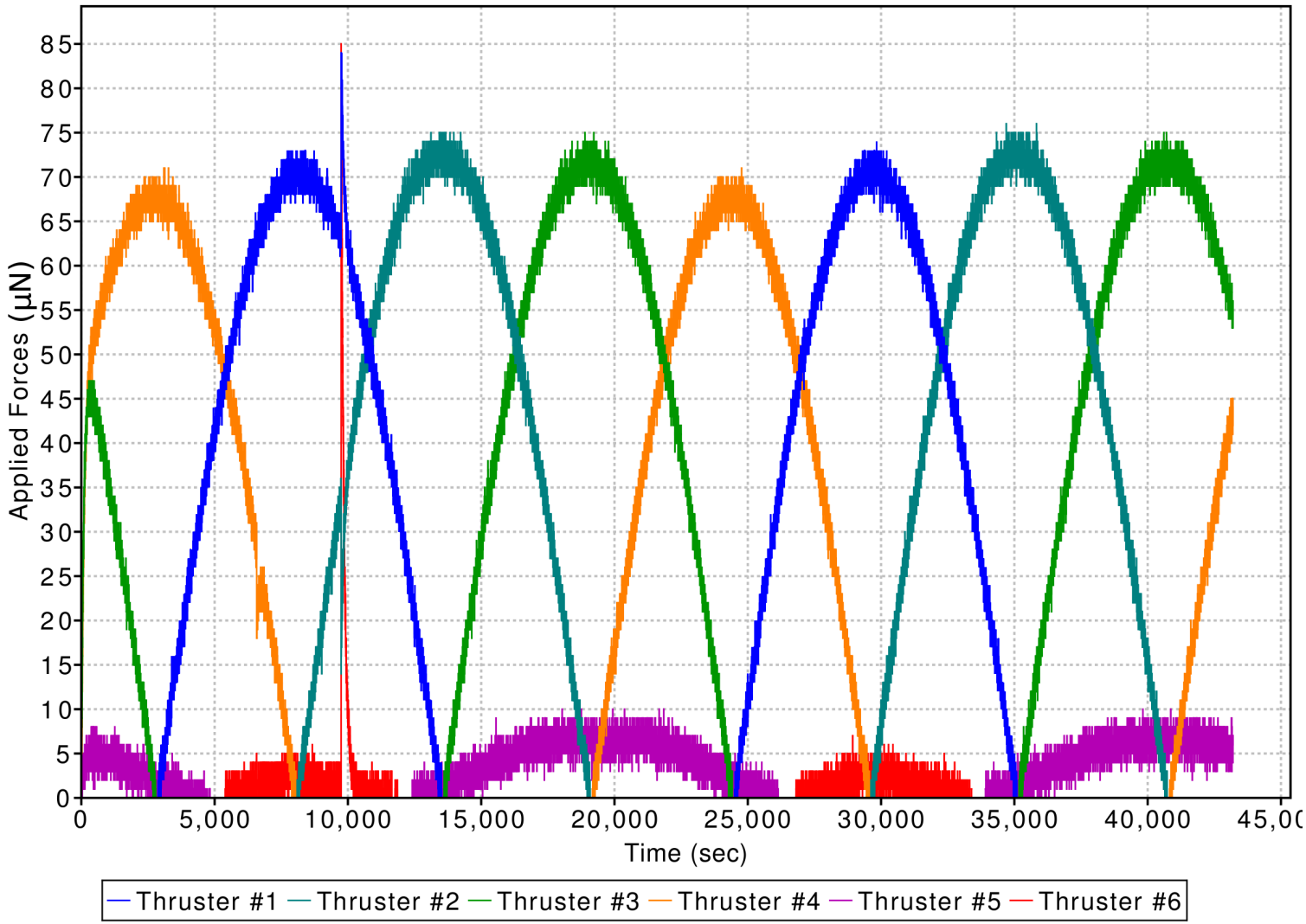
Current Status

- Astrium's AOCS is not implemented yet, simple AOCS instead (provisional)
- Consequence: results are very preliminary

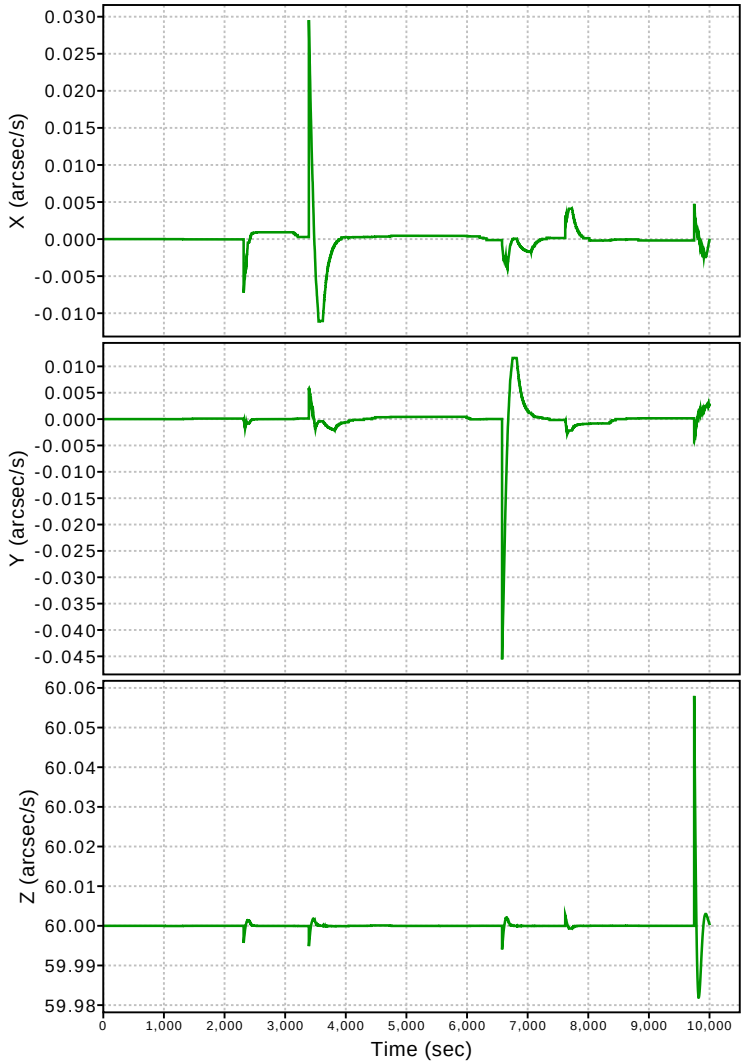
Thrusters Without Noise During 2 Spinning Cycles



Thrusters With Noise During 2 Spinning Cycles



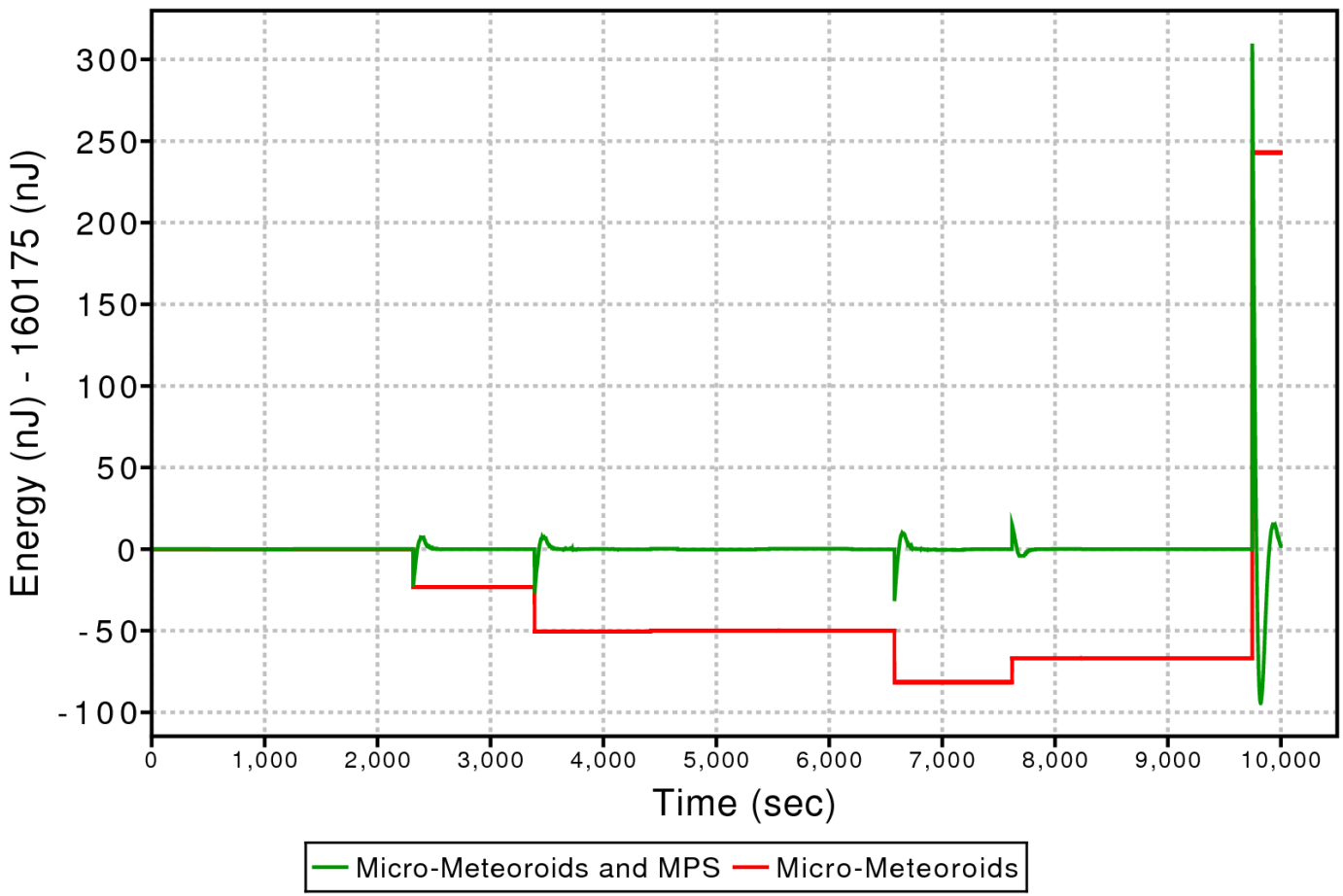
Micro-Meteoroid Impacts + MPS: Angular Rate



- Example: 10 impacts
- Reference Scanning Law: $(0, 0, 60\,\mathrm{arcsec/s})$
- Note: these impacts are not realistic, here they are stronger and more frequent than expected

Micro-Meteoroids and MPS: Rotational Energy

Red line:
only micro-meteoroids
Green line:
thrusters counteracts impacts



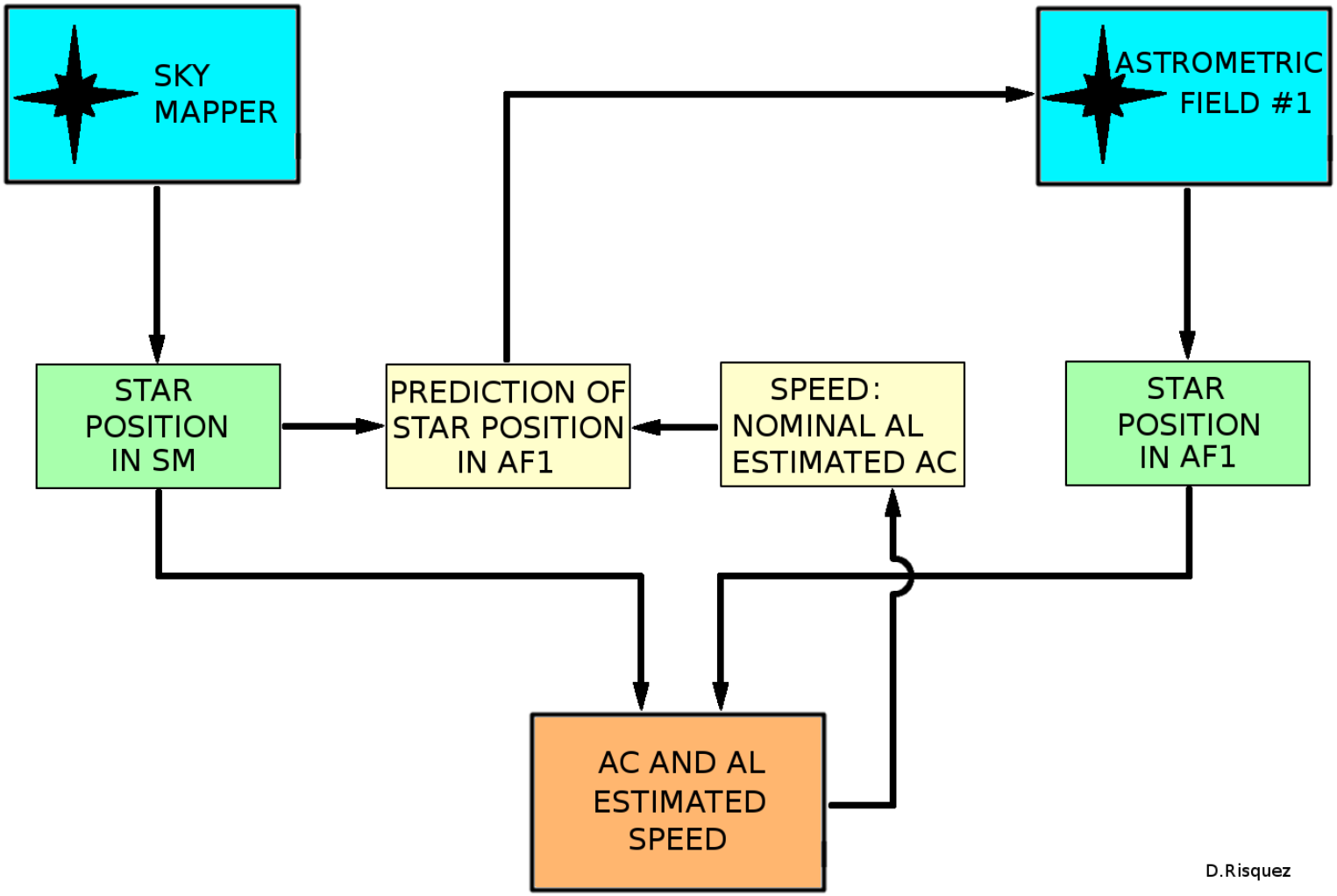
Summary

- This attitude simulation for Gaia is almost developed (code + documentation)
- It takes into account all major physical effects
- The aim is to have a better understanding of the S/C attitude and thus to improve the accuracy of the valuable data

Future Works

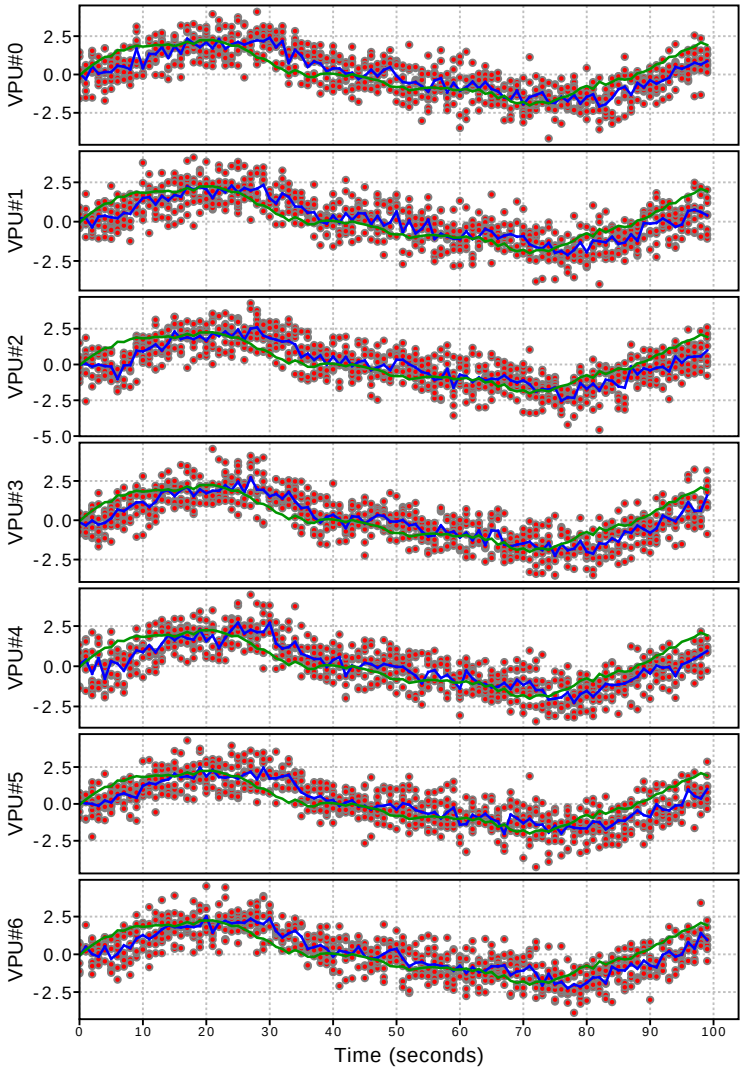
- Complete Astrium's AOCS code
- Complete documentation
- Implement GAM output in Gaia
- Simplify GAM in order to be executed by other users
- Maybe new code implementations: fuel slosh, mechanical oscillations, etc

Star Velocities Measurements

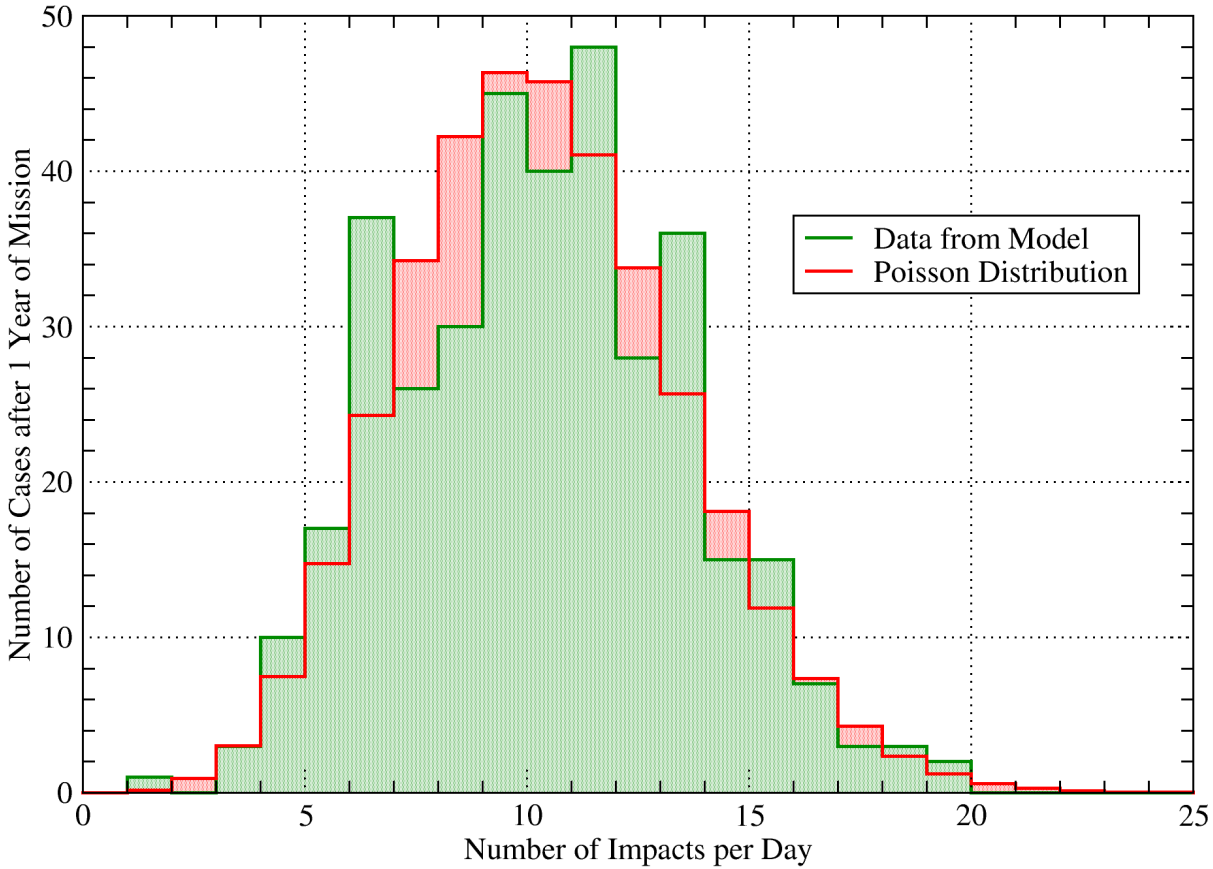


Star Velocities Measurement

- There is a delay ($\approx$ seconds) with respect to the **actual rate**.
- It includes Gaussian noise to **each star velocity** measurement.
- Smooth output: **mean velocities** during transits.

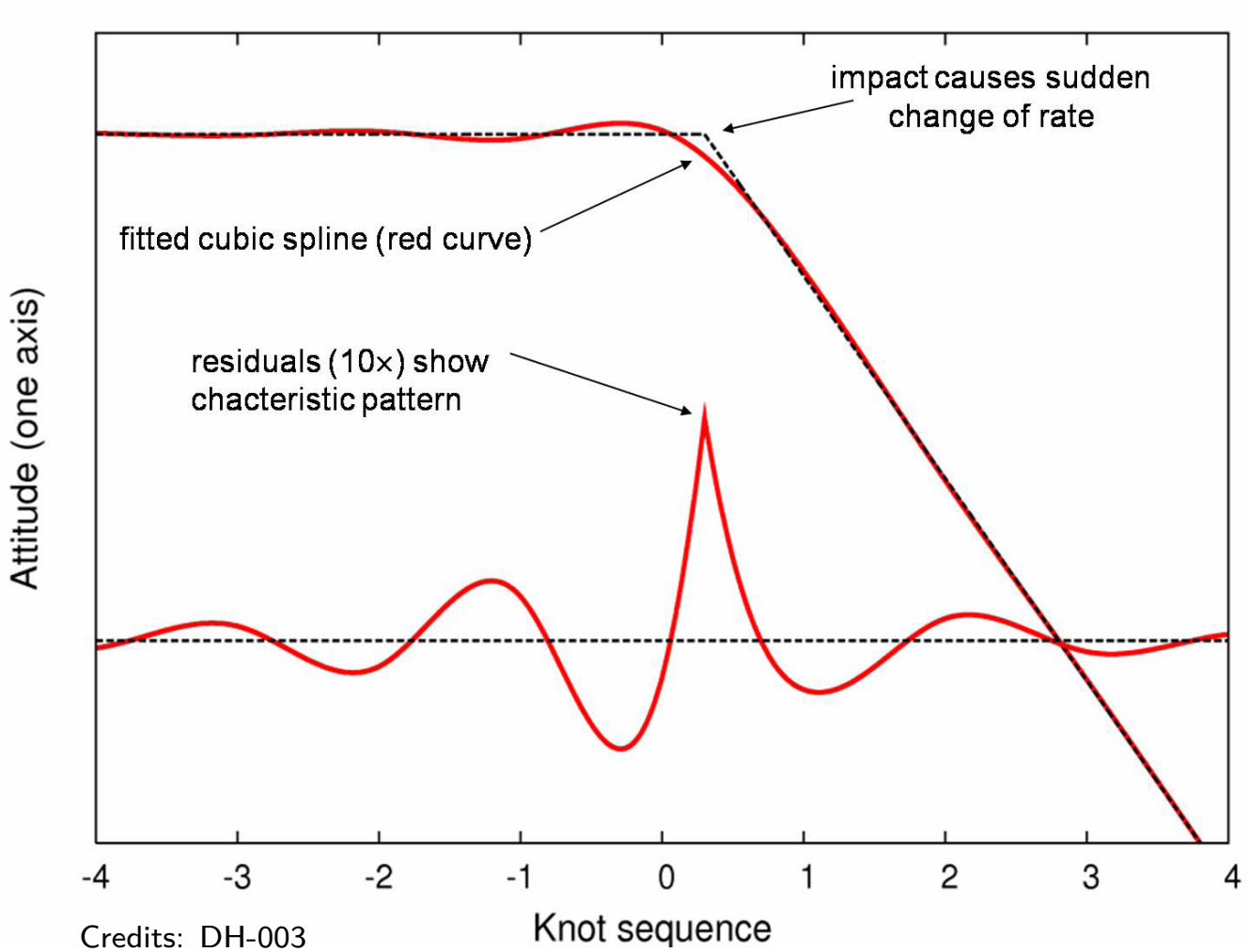


Micro-Meteoroids: Time Distribution



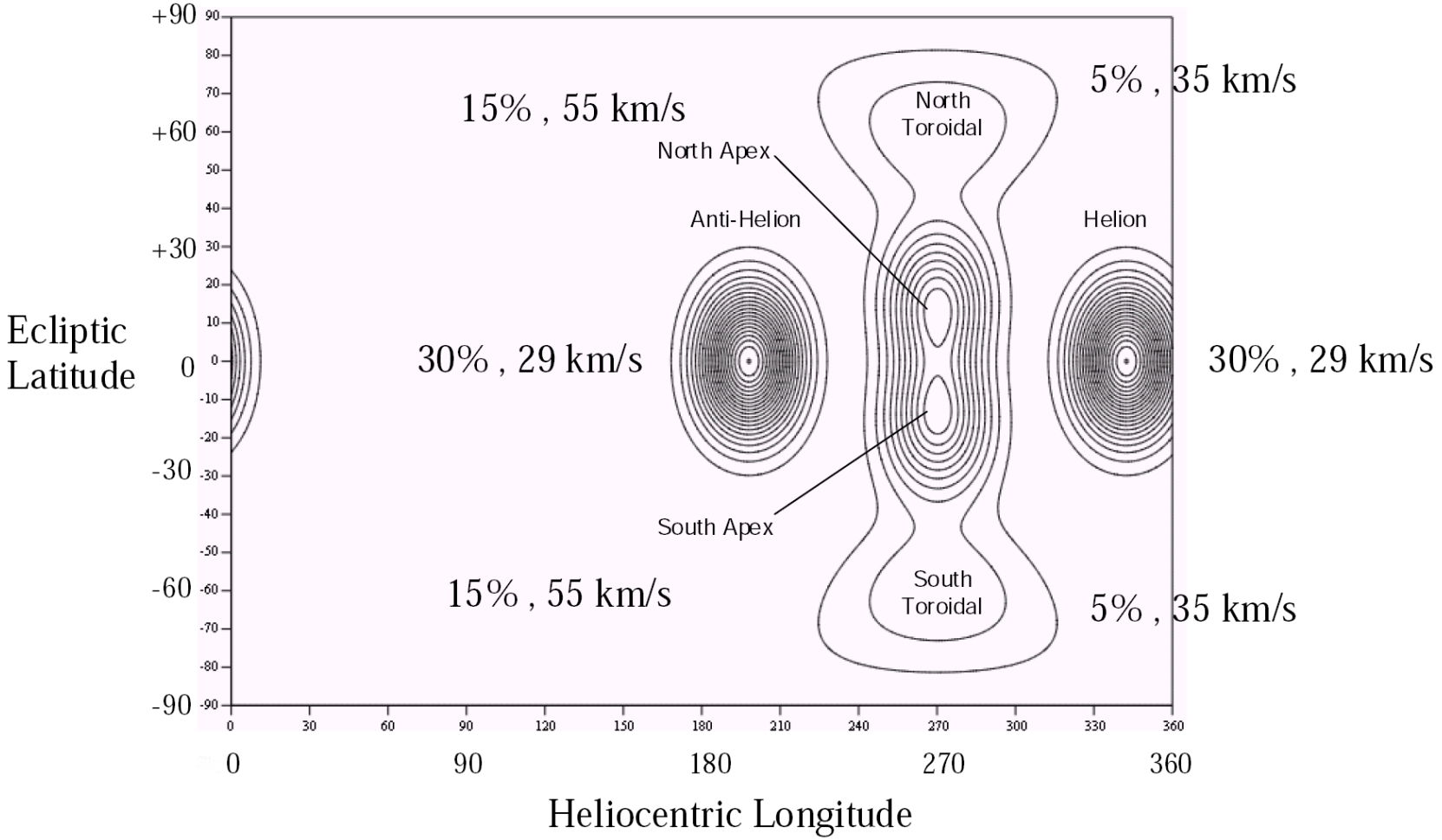
- Expected number of impacts per day, after one year of mission

Micro-Meteoroids: Expected Results



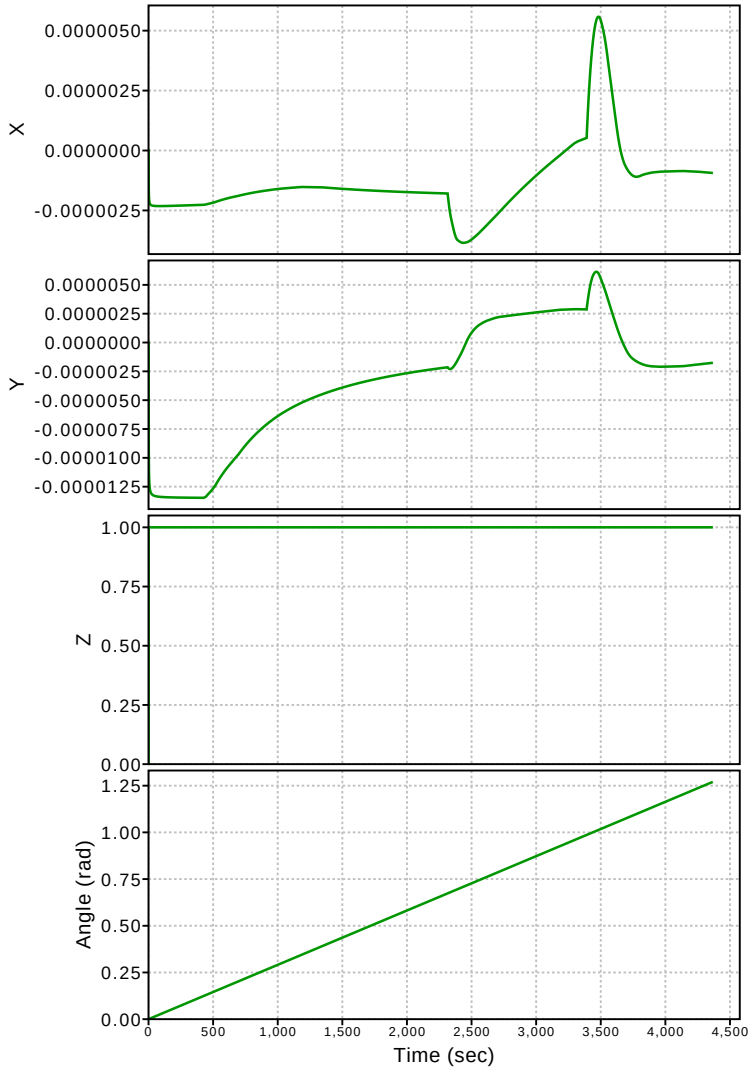
Credits: DH-003

Micro-Meteoroids: Future Improvements, Sky Directions



Heliocentric longitude: the Sun is at 0°, the Earth motion at 270°

Micro-Meteoroid Impacts + MPS: Attitude



- 3 upper plots: rotation axis, unit vector
- 4th plot: rotation angle around the axis
- Reference Scanning Law: $(0, 0, 60\,\mathrm{arcsec/s}) \longrightarrow$ rotation around Z axis at constant angular rate