Development of a hardware-in-the-loop test platform for nanosatellites ADCS integrated with an UKF

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- Hardware
  - Air bearing platform
  - Helmholtz cage
  - IMU Sensor
- Actuators
  - Reaction Wheels
  - Magnetorquer
- Software
  - Orbital propagator
  - UKF
  - Graphical visualization

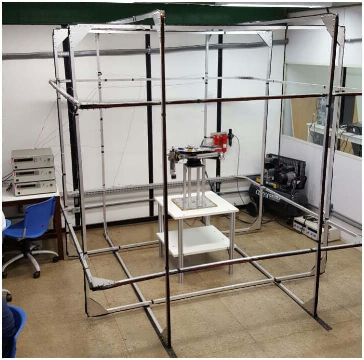
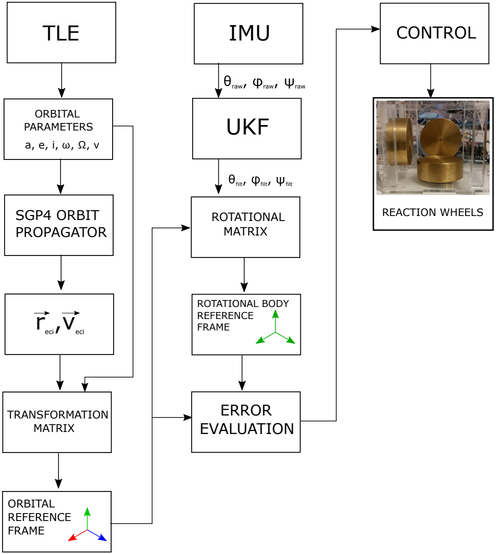


Figure: General view of the LAICA's platform.

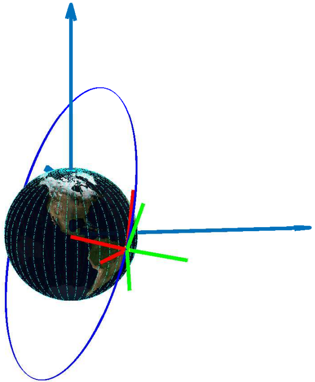
Objective: the objective of this work is to develop a hardware-in-the-loop system to test nanosatellites actuation systems

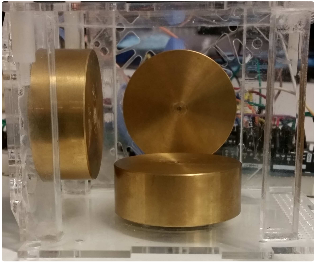
- Frictionless condition.
- Use of three small reaction wheels
- COTS gyro measurements
- This work is a first attempt to close the control loop (ukf implemented in matlab and first control test of the wheels)
- Derivation of the wheels model

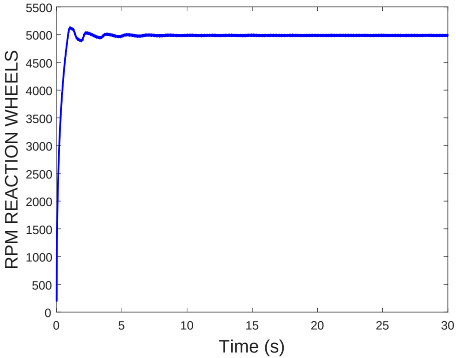
Architecture of the Simulator



Graphical view of the software simulation which relates the body frame axes with to the orbital frame axes.







Reaction wheel's model obtained from the step response:

$$\frac{\Omega}{V_c} = \frac{51.42s^4 + 2.004 \cdot 10^4 s^3 + 3.849 \cdot 10^5 s^2 + 9.916 \cdot 10^5}{s^4 + 93.47s^3 + 552.5s^2 + 2618s + 7729} \quad (1)$$

Due to the platform nonlinear model, it was implemented an Unscented Kalman Filter (UKF) algorithm.
The estimated state vector is given by:

$$x = \begin{bmatrix} \phi \\ \theta \\ \psi \end{bmatrix} \tag{2}$$

The system model is presented in Eq. 3.

$$g(x_t, u_t, w_t) = x_t + \Lambda(\boldsymbol{x}) u_t \Delta_t + w_t \ , \tag{3}$$

Where,

$$\Lambda(\boldsymbol{x}) = \begin{bmatrix} 1 & sen\,\phi\; tg\,\theta & cos\,\phi\; tg\,\theta \\ 0 & cos\,\phi & -sen\,\phi \\ 0 & sen\,\phi\; sec\,\theta & cos\,\phi\; sec\,\theta \end{bmatrix} \tag{4}$$

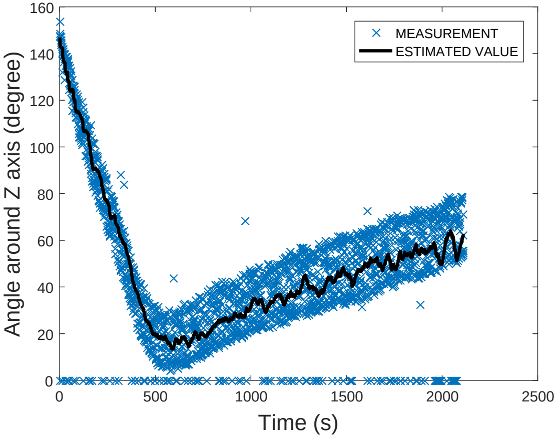


Figure: Unscented Kalman Filter output in black and measurement of the data in blue.

To test the hardware-in-the-loop system it was implemented a PD controller presented in Equation 5 in order to control the orientation of the satellite around the Z axis using the reference provided by the software. According to (A.Wu, 1999), the discrete PD control law is giving by:

$$PWM(k+1) = K_p * error(k) + \frac{K_p * T_d}{T}(error(k) - error(k-1)), \tag{5}$$

Where $error(k) = \psi(k)_{ref} - \psi(k)$

PD Controller Results

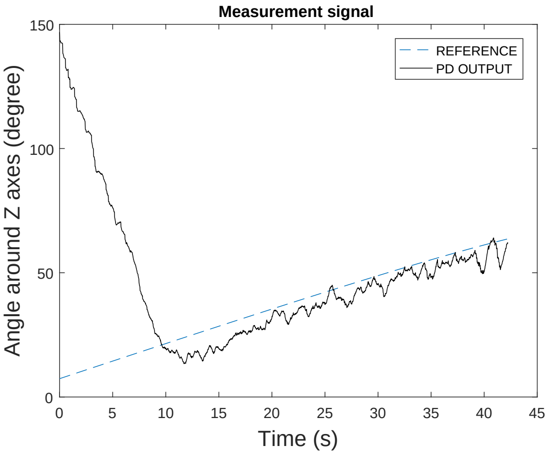


Figure: System output under actuation of the PD controller.

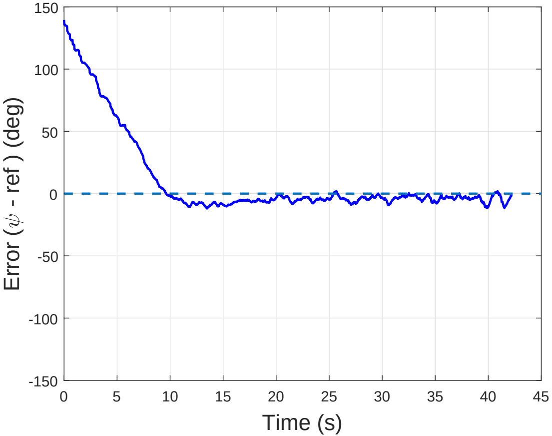


Figure: Error variation with the time.

- In this work, the body's orientation was reconstructed using an UKF, a control law was tested and a mathematical model from the reaction wheel was obtained.
- The UKF provided a tolerance to noise and package loses and improved the efficiency of the PD controller.
- The hardware-in-the-loop system was capable of simulate a tracking operation.
- In the future, the UKF will implemented on board computer
- Other control strategies will be implemented. The PD presented here was just a preliminary test.

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Thank You!

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