POLITECNICO DI MILANO

Aerospace Science
and Technology
Department

SKYWARD EXPERIMENTAL ROCKETRY

LOW COST MEMS IMU CALIBRATION FOR AEROSPACE STUDENT ACTIVITIES

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Outline

- Skyward Experimental Rocketry
- MEMS IMU in student sounding rockets
- MEMS IMU error model
- Calibration platform
- Calibration platform sequence
- Hierachical calibration procedure
- Accelerometer calibration
- Gyroscope calibration
- Tested IMUs
- Calibration results
- Temperature sensitivity

Skyward Experimental Rocketry

Student association since 2012

Design, testing realization & launching of experimental sounding rockets

More than 50 members since 2013

Company-like organization

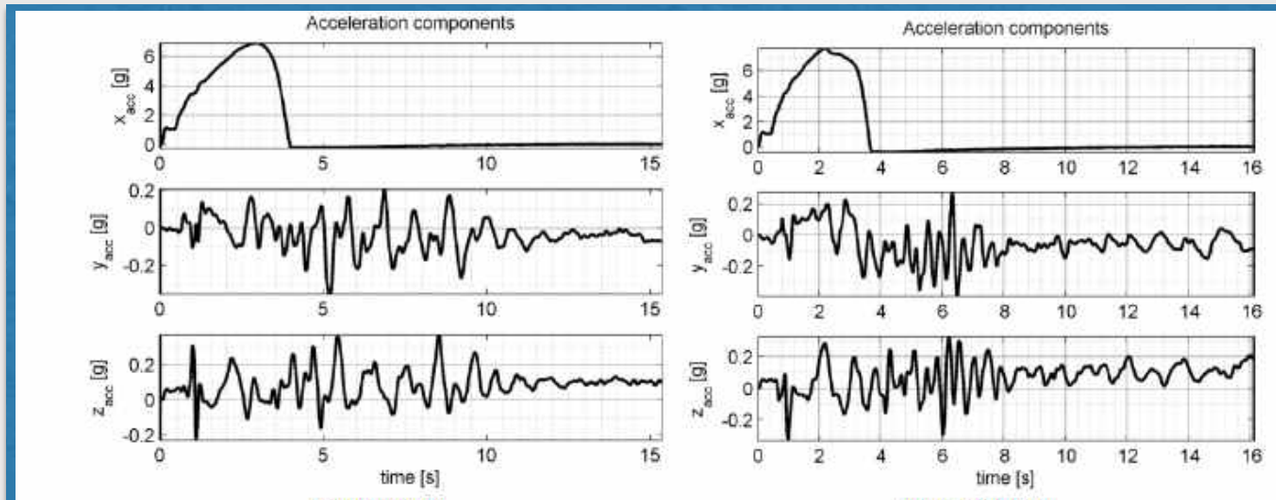
I launch [nov 2013]

Parachute failure

II & III launch [jun 2014]

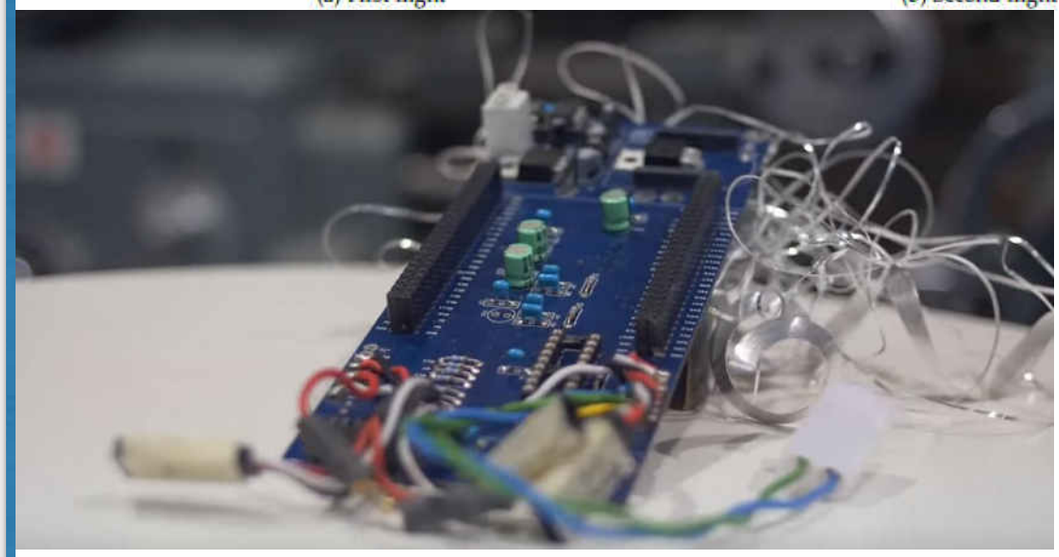
No Failures

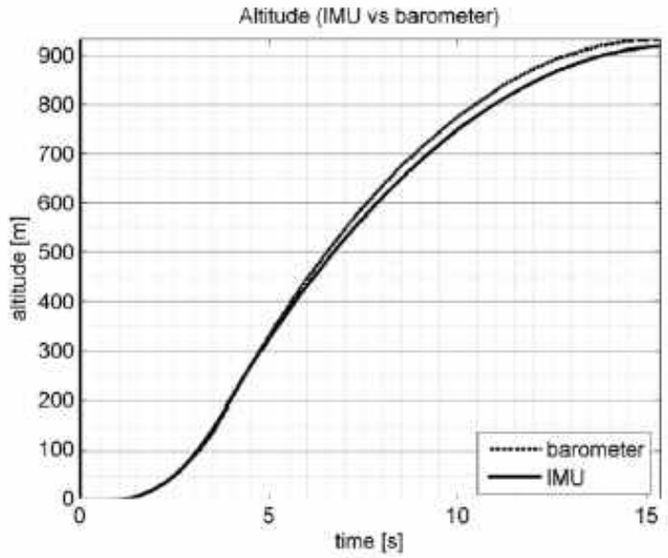
MEMS IMU in student sounding rockets



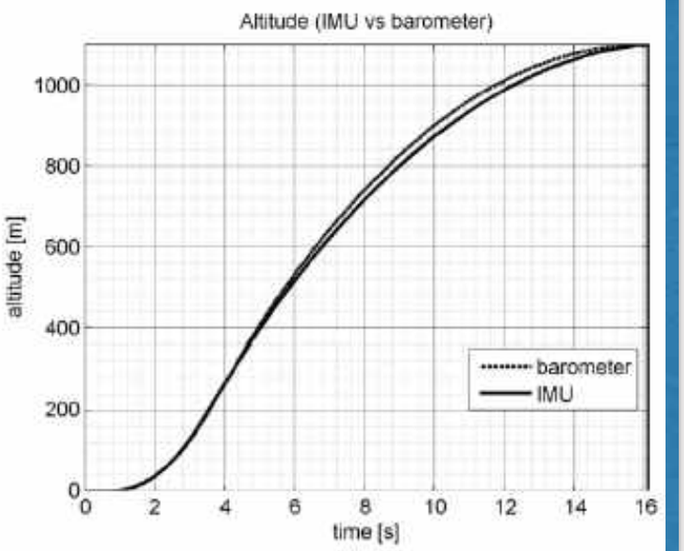
(a) First flight

(b) Second flight

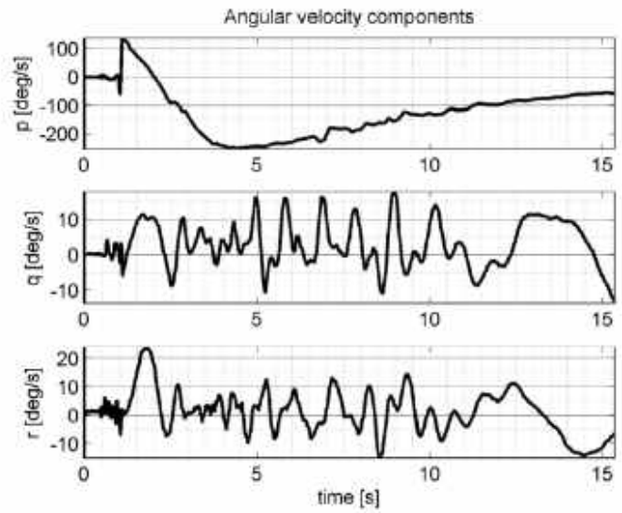




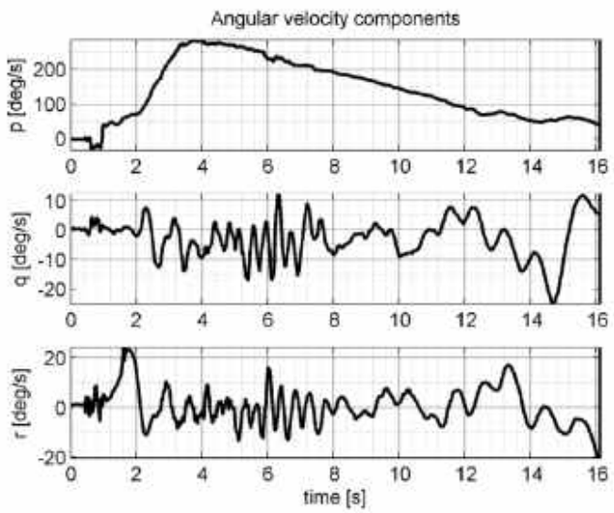
(a) First flight



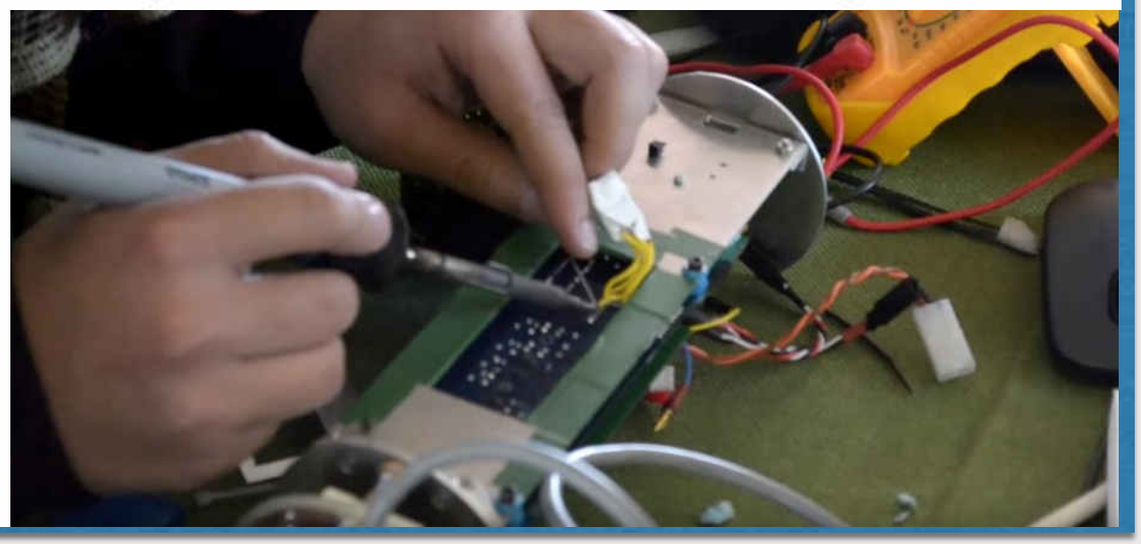
(b) Second flight



(a) First flight



(b) Second flight



MEMS IMU error model

$$\mathbf{a}_b = \mathbf{R}_{mis}\mathbf{T}_a\mathbf{S}_a\mathbf{a}_m + \mathbf{b}_a + \mathbf{n}_a$$

IMU placement attitude errors

Sensor noise

Non orthogonality of three axis IMU

$$\mathbf{T}_a = \begin{bmatrix} 1 & -\beta_{yz} & \beta_{zy} \\ \beta_{xz} & 1 & -\beta_{zx} \\ -\beta_{xy} & \beta_{yx} & 1 \end{bmatrix}$$

Scale factor

Bias

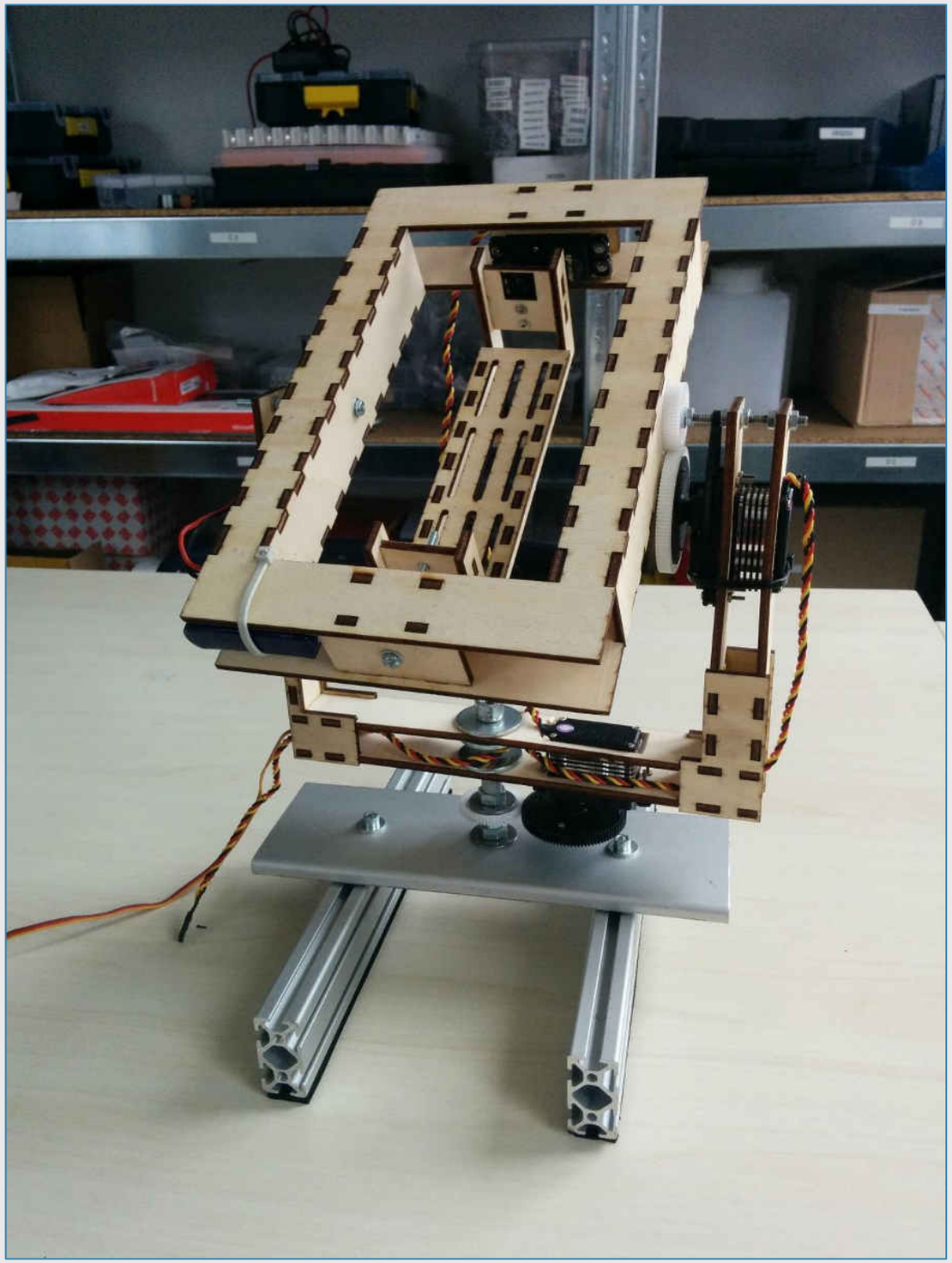
Principal concern for aerospace vehicle control

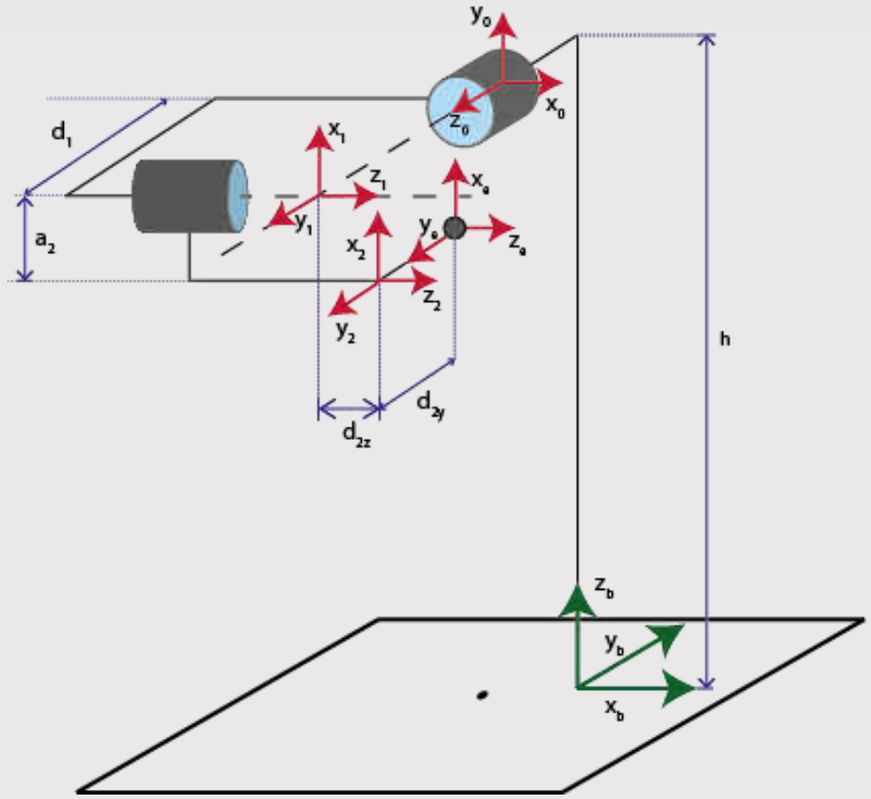
Configuration dependent

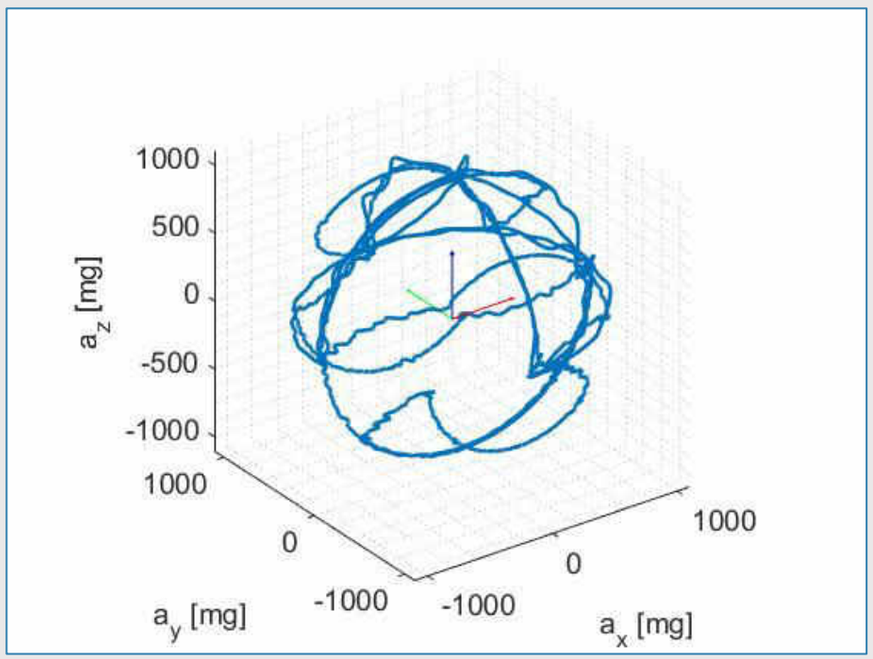
Long term error performance neglected

High Temperature sensitivity

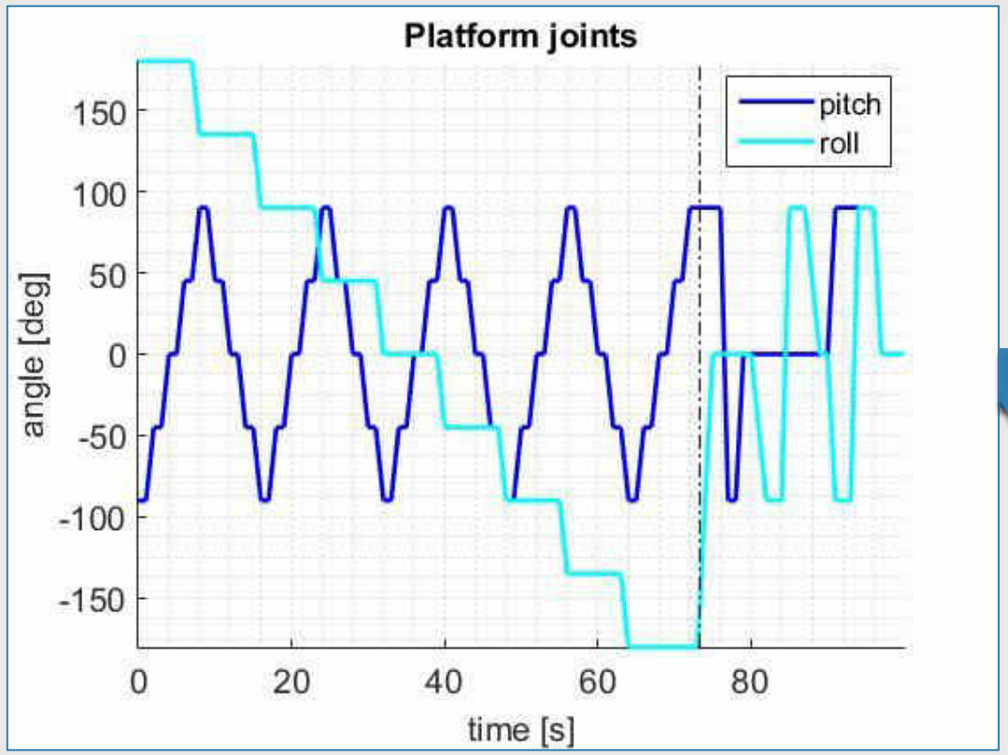
Calibration platform

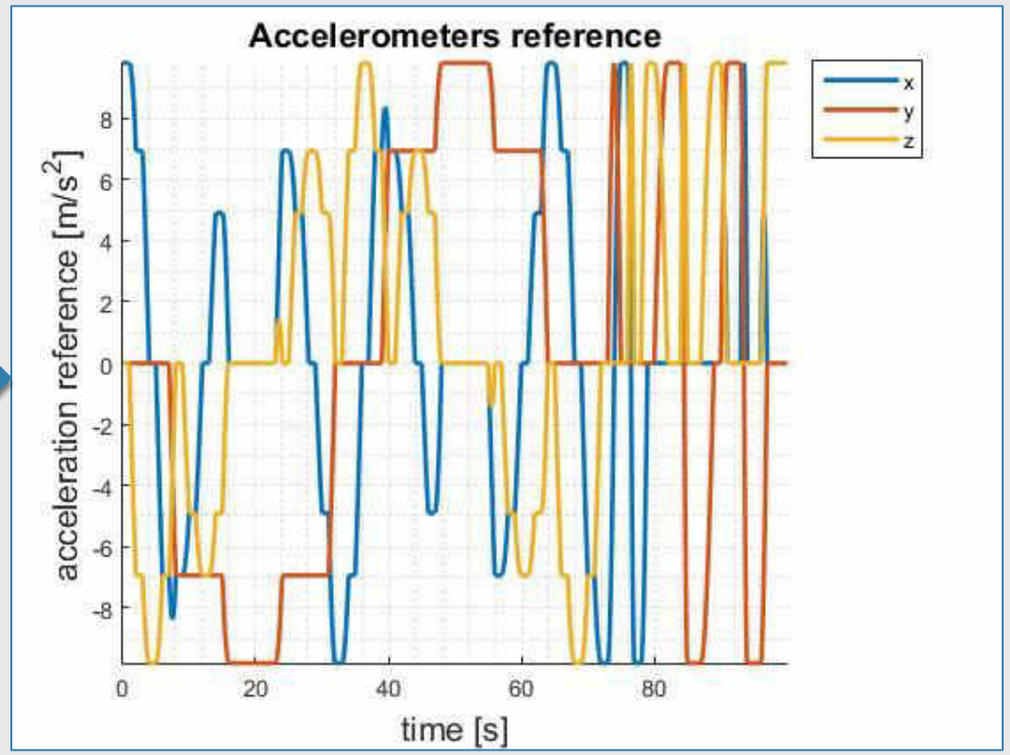


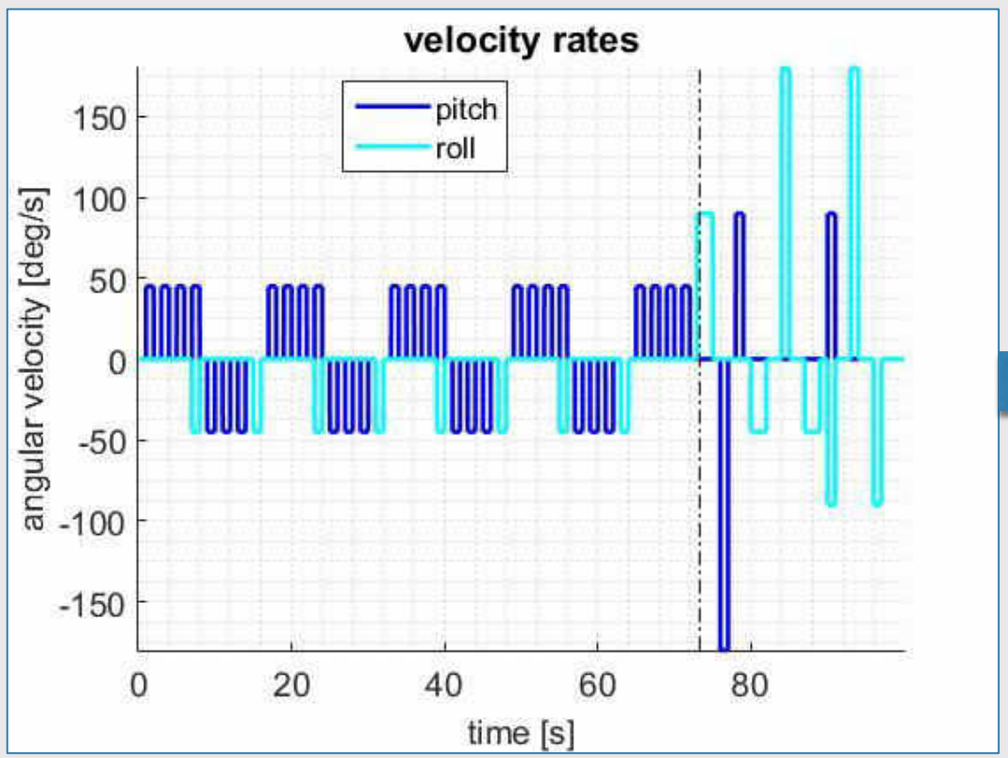


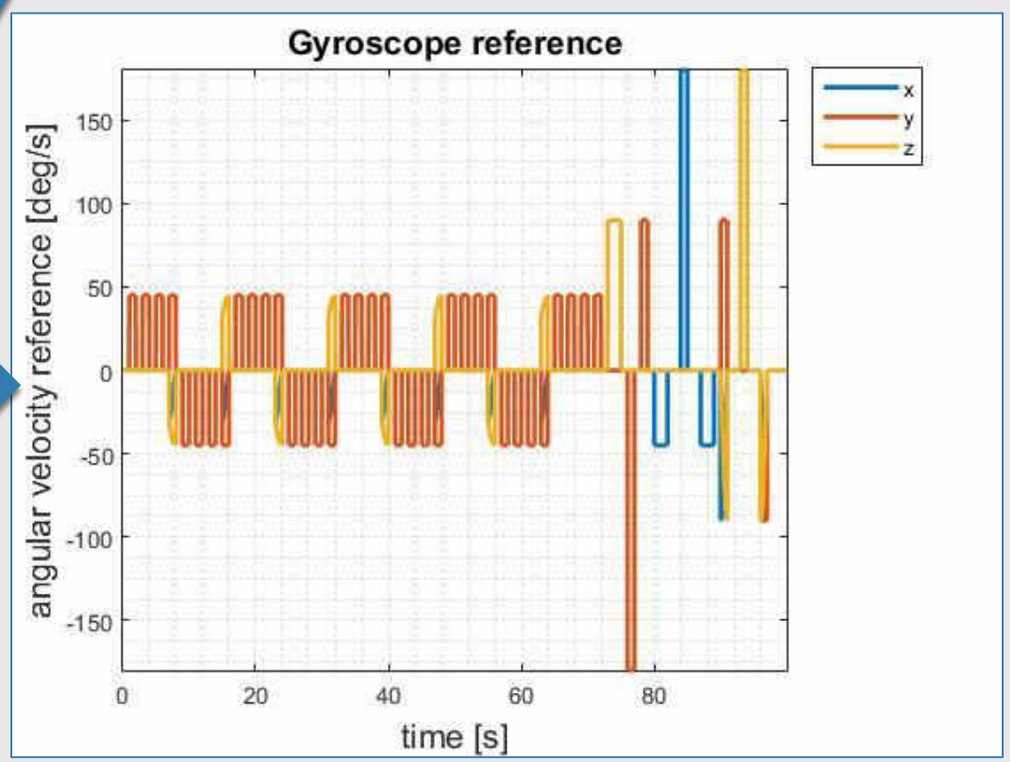


Calibration platform sequence









Hierachical calibration procedure

Registration

Step - 1

Time shift
Bias
Scale

Step – I

Increasing complexity

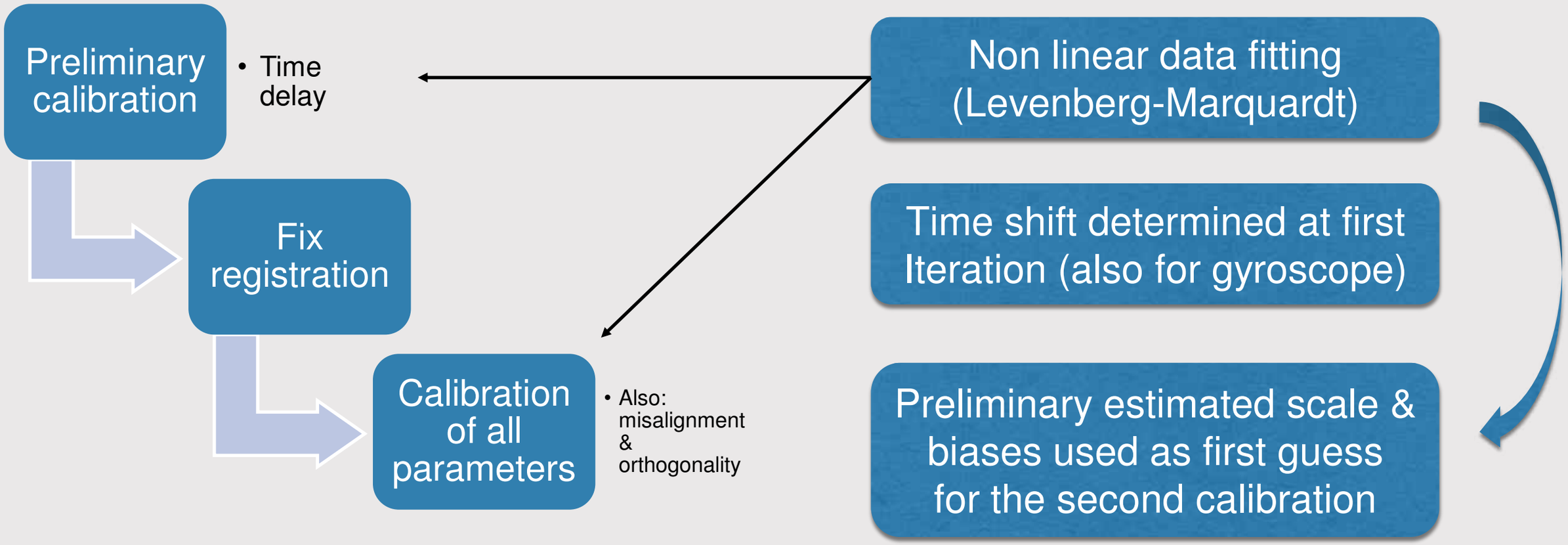
(fixed registration)

Final Step

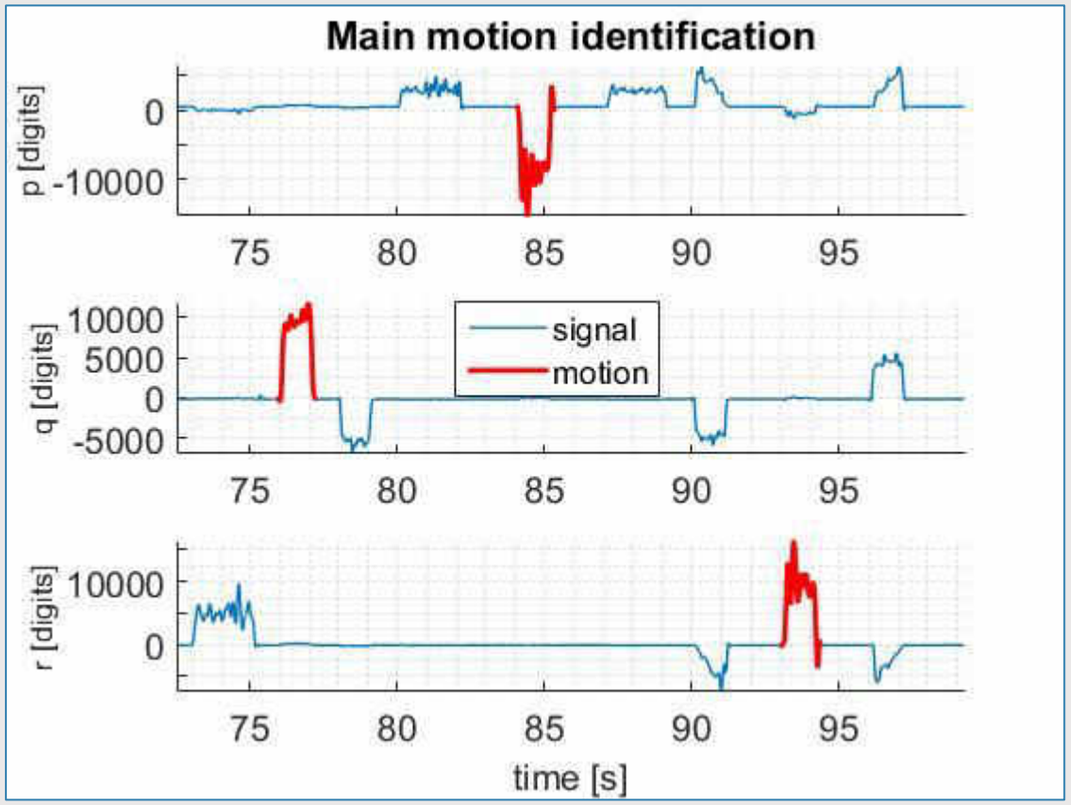
All parameters

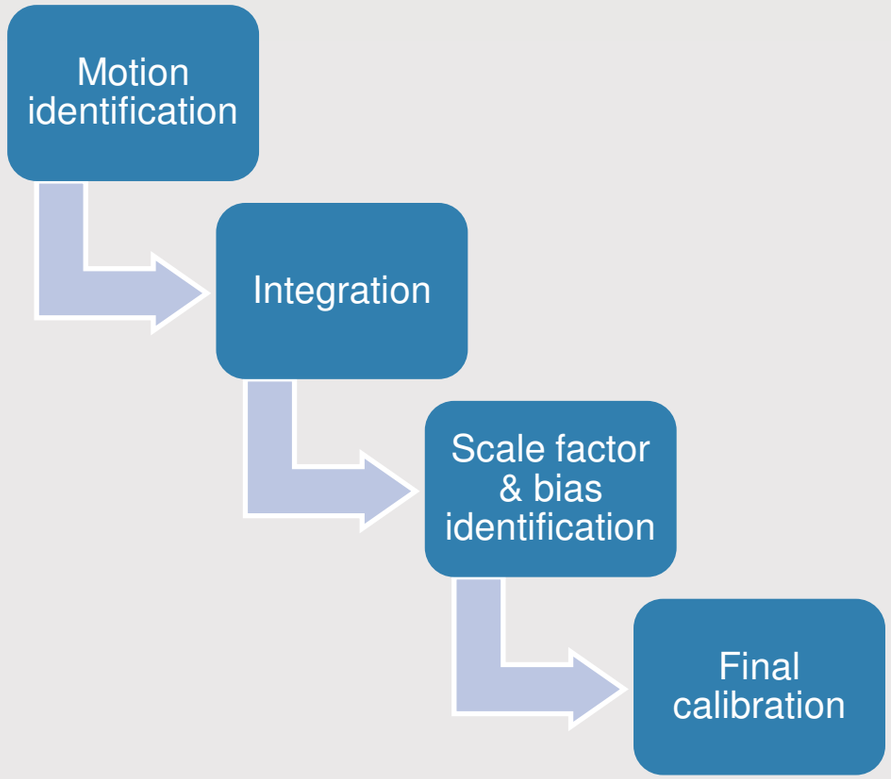
Check the goodness of each iteration by comparison with the previous

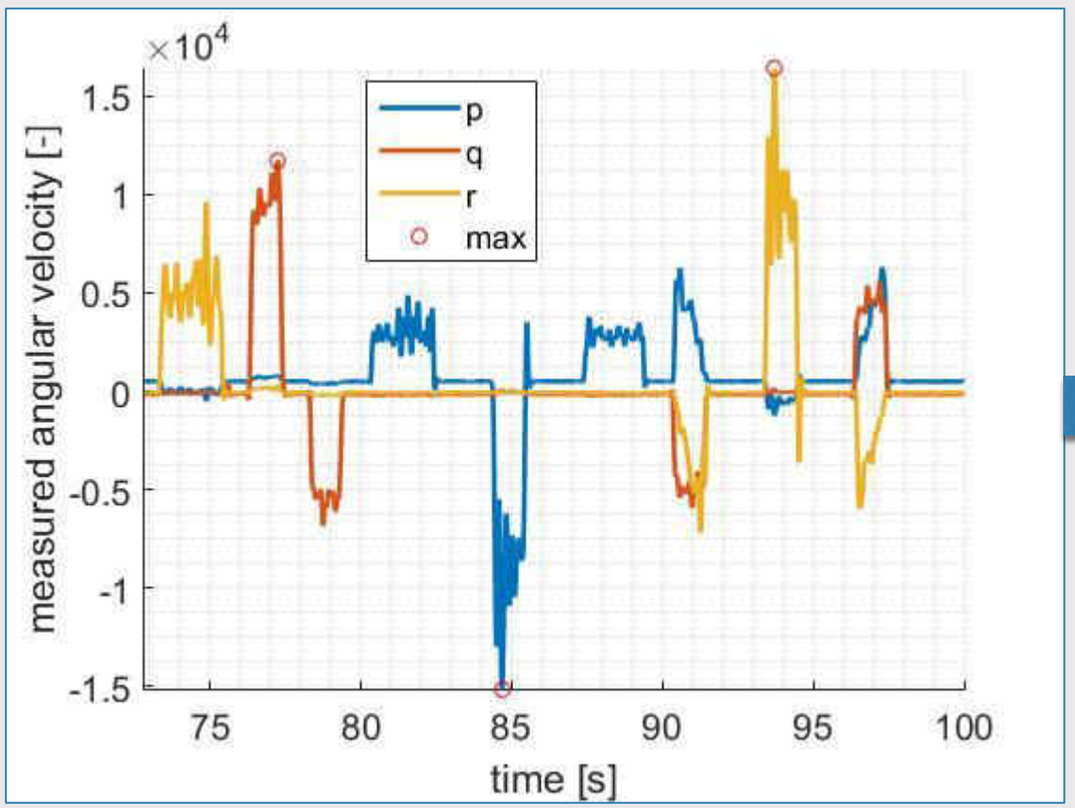
Accelerometer calibration

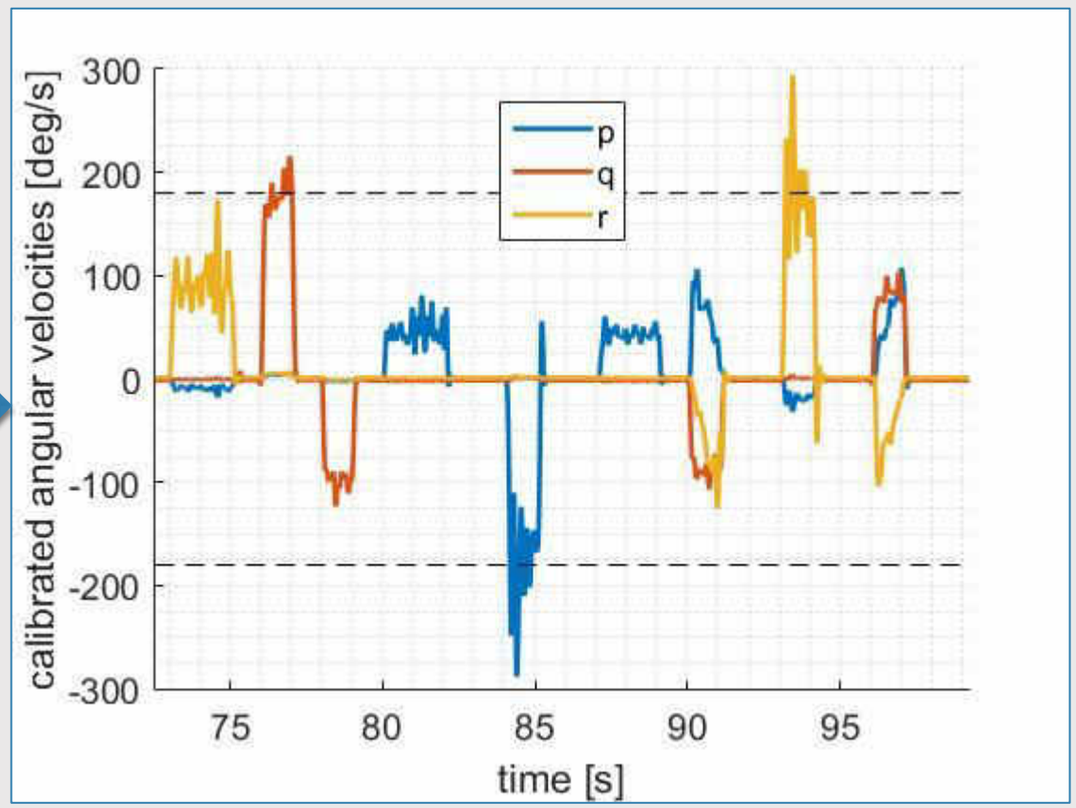


Gyroscope calibration

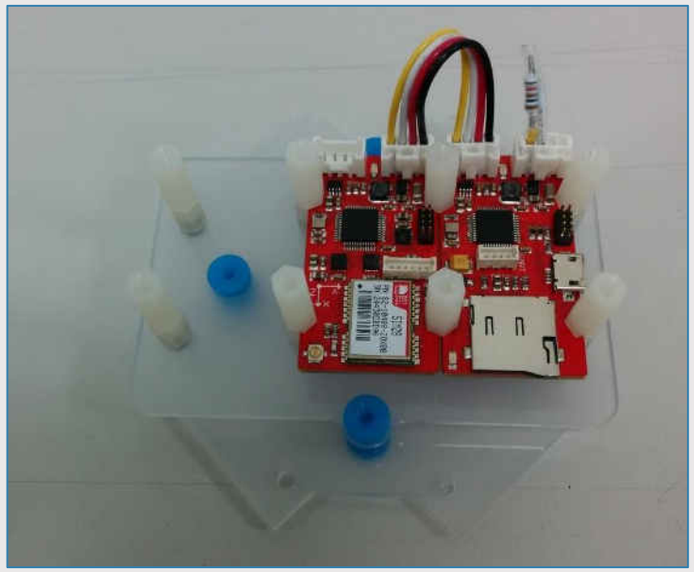


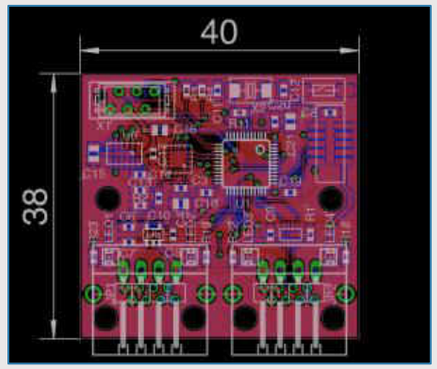






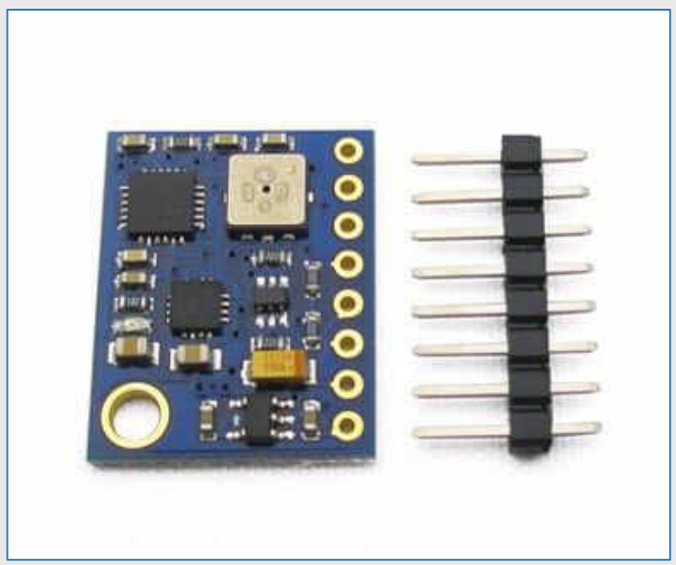
Tested IMUs





R2P

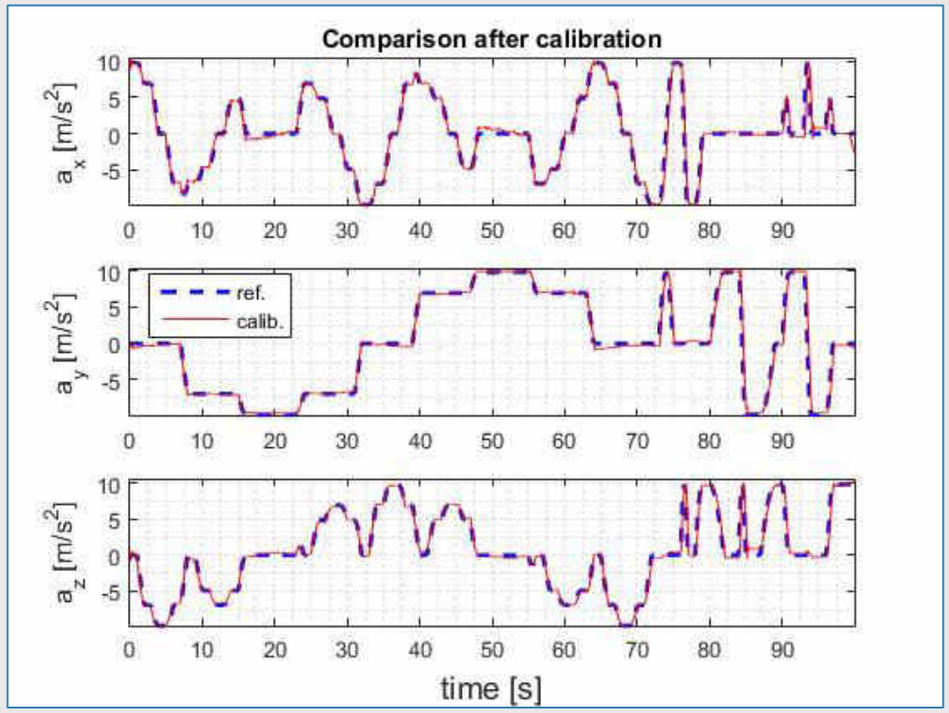
Developed @ Polimi
easy to connect

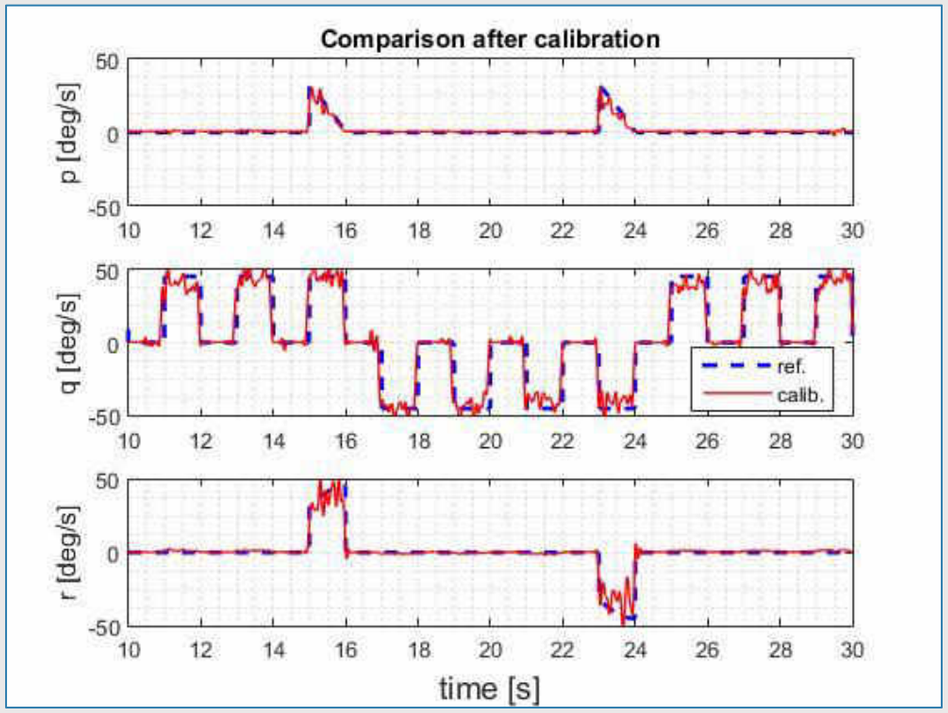


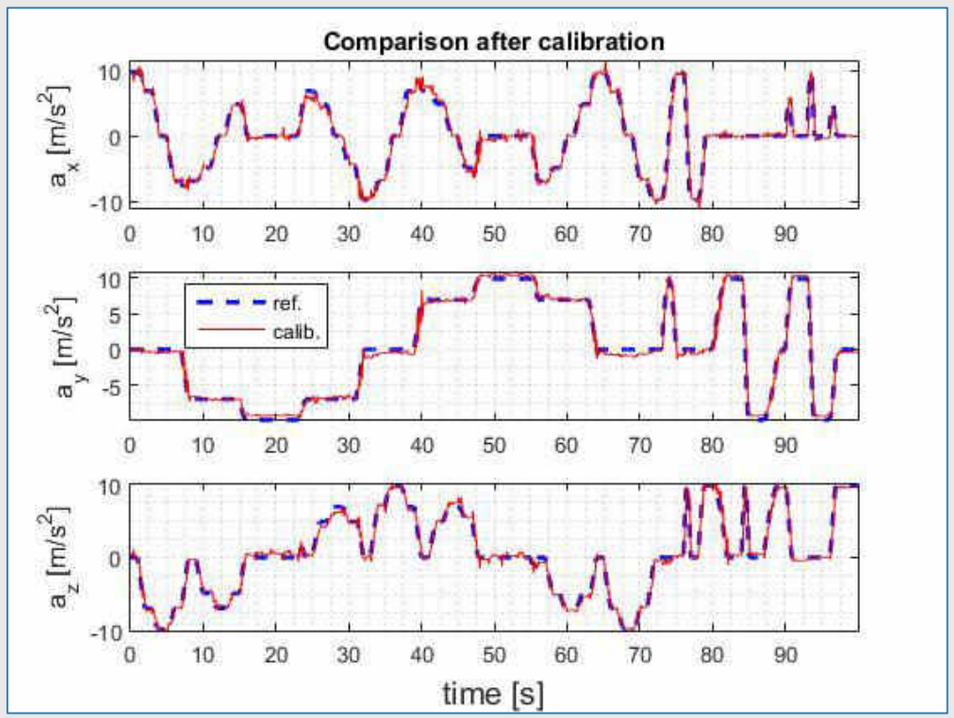
GY-88

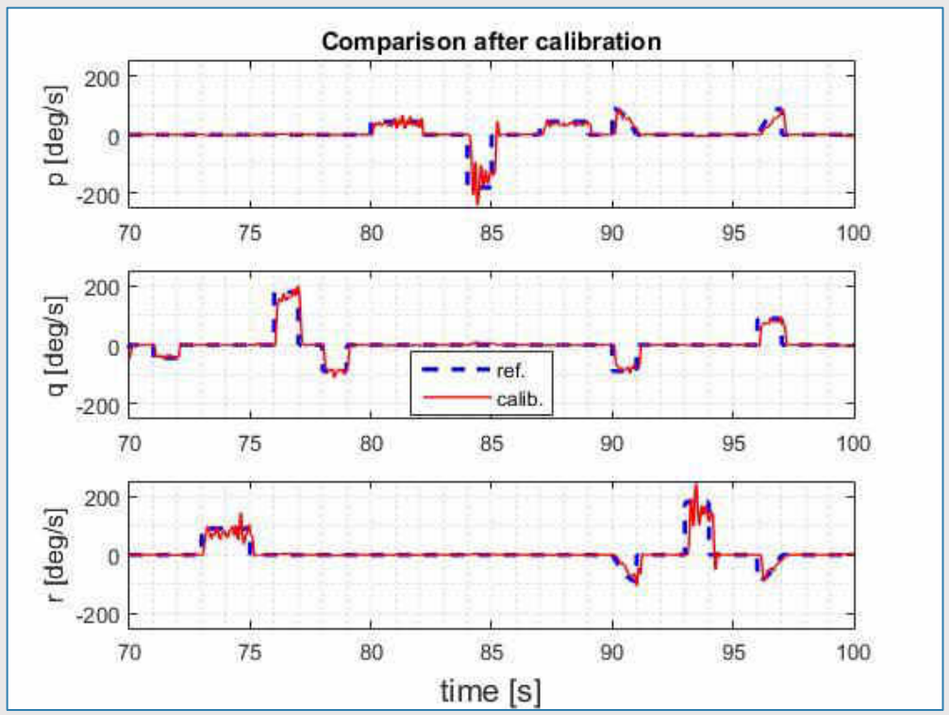
Low cost and popular

Calibration results

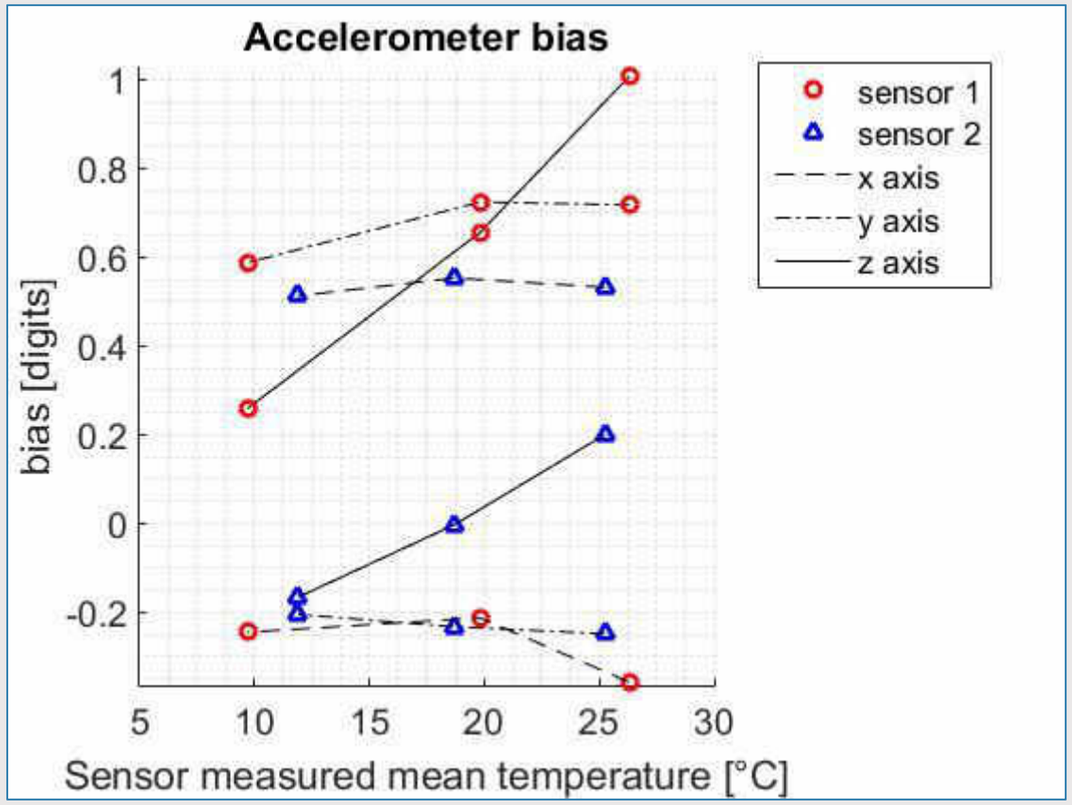


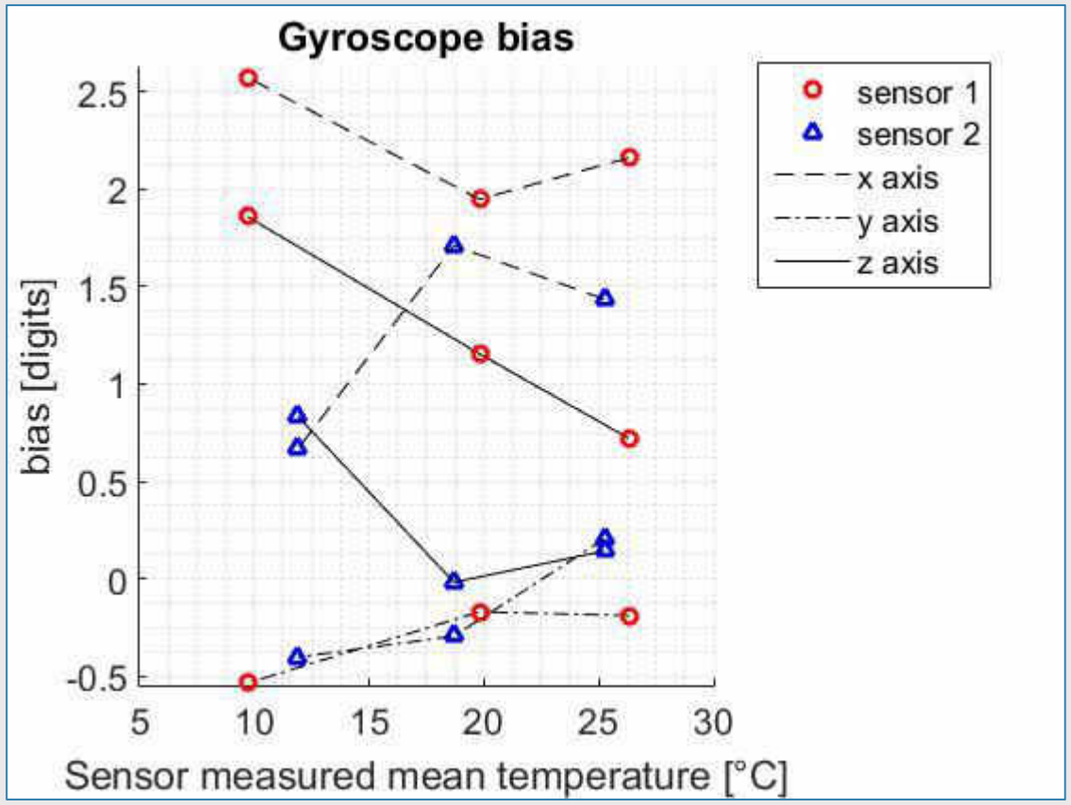






Temperature sensitivity





Temperature affects the biases. Many trials are needed to model the variation. For on-board applications temperature compensation or active temperature regulation may be necessary depending on the use of the measurements

Conclusion

- A hierachical and instructive calibration procedure has been devised,
- an experimental set-up has been prepared,
- experiments were made by students,
- technical requirements have been investigated.

The calibration procedure has produced good and coherent results.

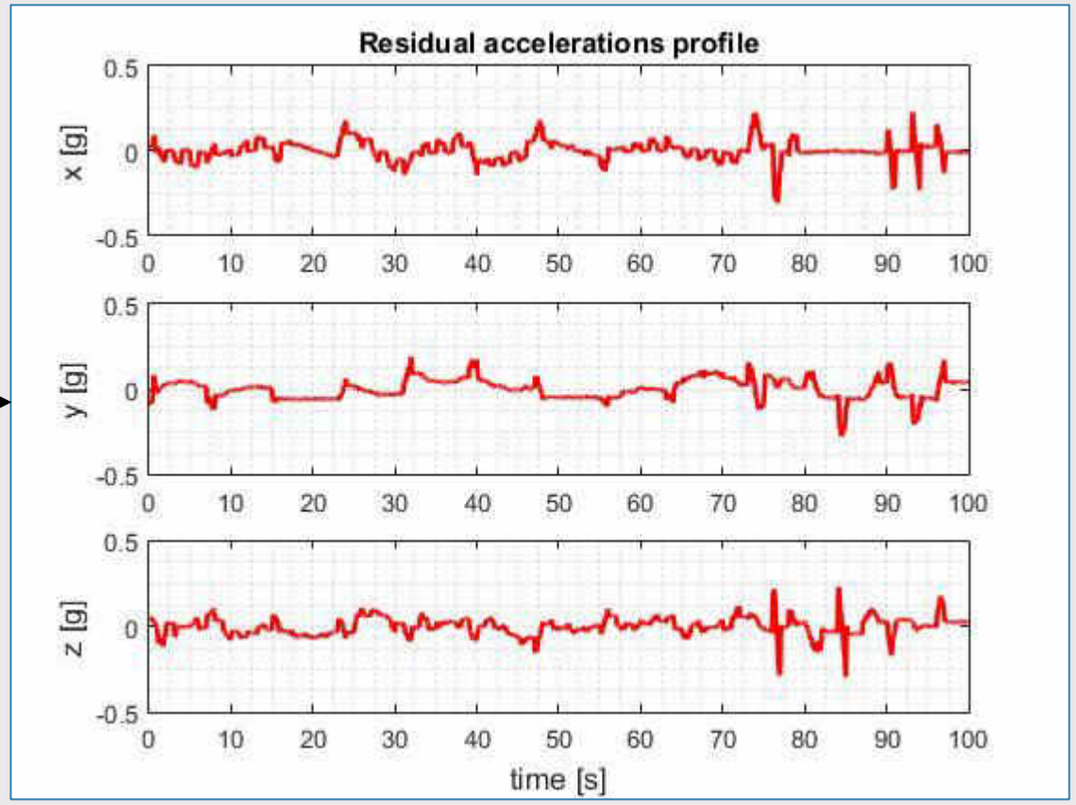
Open problems and future activity

IMU position on the platform induces non modeled accelerations

Gyroscope g-sensitivity has not yet been tested

More tests required to characterize temperature influence

Calibration improvement



Identify a procedure for on-board compensation [digital/analog]

Identify requirement for filtering of IMU data for control purpose

Thank you for your attention.

Questions?

http://www.skywarder.eu