Line-of-sight stabilization for satellite high performance pointing and tracking systems

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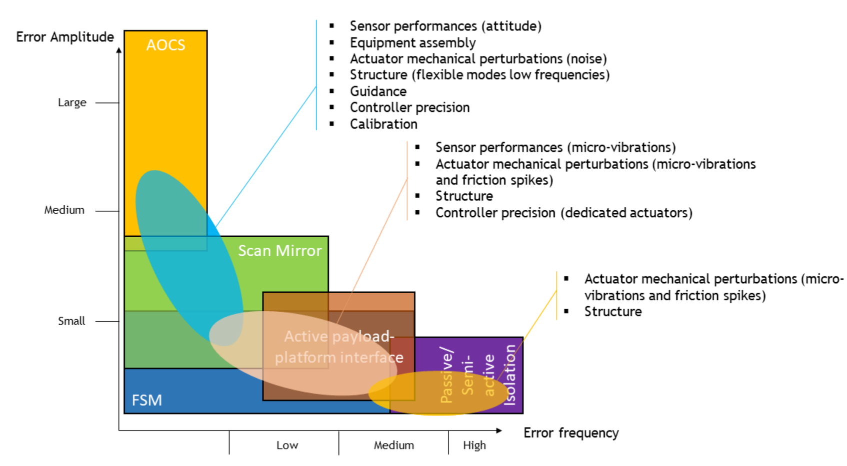
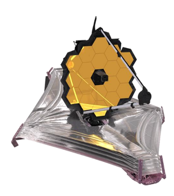
PHD

MOTIVATION

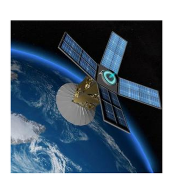
Earth observation, **astronomy** and **free space optical communications** (including **QKD)** are examples of areas where fine and stringent pointing requirements are needed!

Other important field is on cubesat market, in which hardware limitations based on cost implies ingeneral low pointing accuracy.



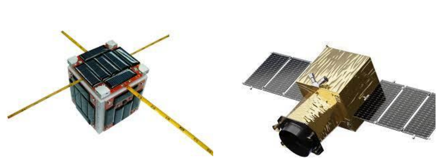


ASTRONOMY / IR



EARTH OBSERVATION

FSOC AND QKD



CUBESATS

OBJECTIVES

Given that this trend in requirements is expected to increase in the coming decades for astronomical missions, Earth observation, and optical-laser communications, this thesis will address **the analysis** and improvement of current proposed **solutions** to date in terms of hardware selection, system architecture, and **advanced control algorithms for line-of-sight (Los) stabilization.**

Training and knowledge enhancement in the field of line-of-sight stabilization pursuing an industrial PhD with SENER

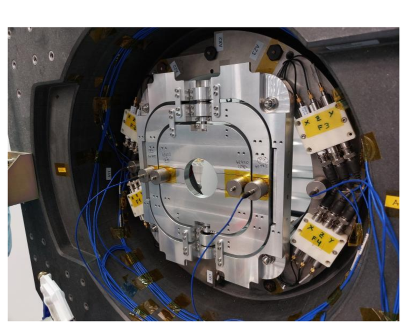
- Dynamics and control **simulation** model
- **Architecture** analysis
- **Advanced** and robust control algorithms
- Simulation and **experimental** testing

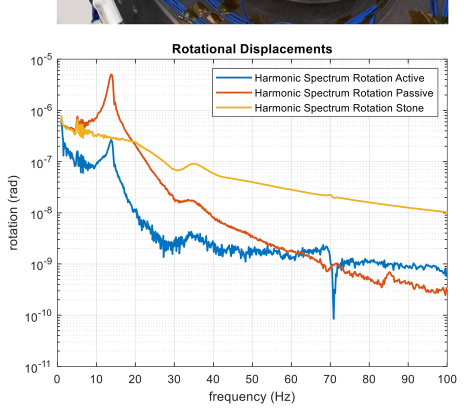
BACKGROUND CUBESATS (LOSSOP-ESA)

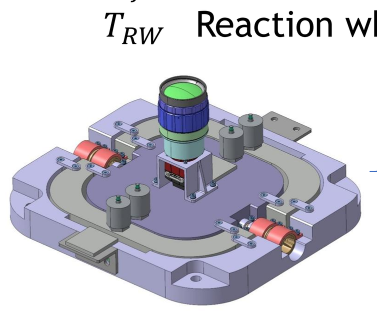
In frequency domain, the LOS Stabilization Module can be defined as a transfer function L(s).
The mathematical description of L(s) can be obtained by:

$$L(s) = \frac{\theta_{req}}{(H_{T\rightarrow\theta} + H_{flex}) \cdot W_f \cdot T_{RW}}$$

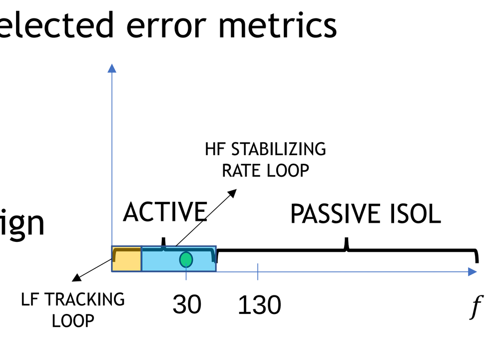
θ_{req} Required pointing error metric
$H_{T\rightarrow\theta}$ AOCS transfer function
H_{flex} Structural dynamics transfer function
W_f Weighting function based on selected error metrics
T_{RW} Reaction wheel input torque







Sensors
Actuators
Mechanical Design
Electronics
Software

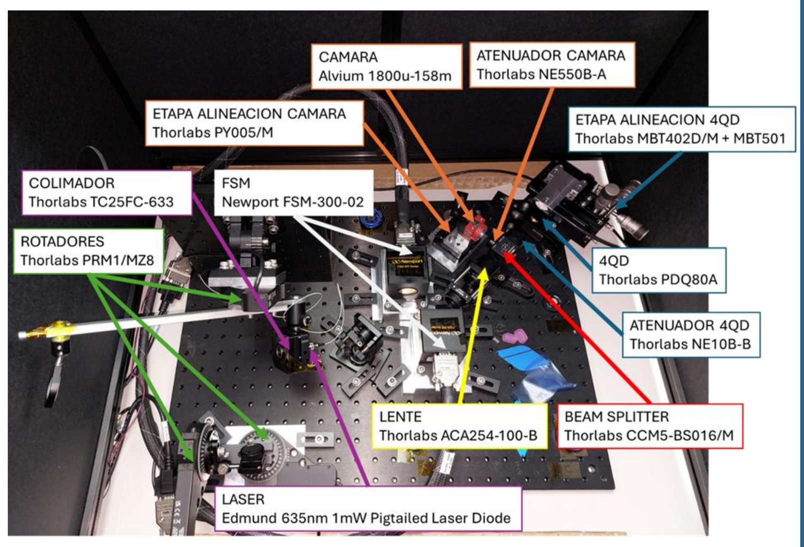


BACKGROUND QKD / FSOC (QKD LEO)

The main objective is to develop a real technological demonstrator based on two static terminals on earth (Tests in 2026). **SENER** is the prime contractor for this project supported by the **CDTI**.
One of the terminals is an **On Ground System** (Telescope) the other one represents the **Payload** (Satellite).

Pointing acquisition and tracking is one of the most critical subsystems of the demonstrator, and it mainly consists of control through a **coarse pointing mechanism** (Telescope-AOCS) and a **fine one based on a** Fast Steering Mirror (FSM).

Currently in progress!



STATE OF THE ART

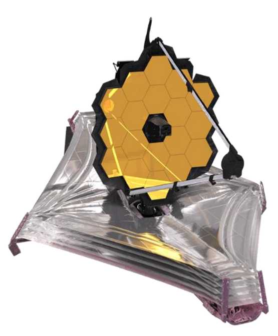
The possible methods are classified depending on the system in which they act. They can act on the actual source of the **disturbance** (hardware improvement), the interface between the source and the spacecraft, the transmission path of the disturbances, the interface between the payload and the structure, and/or the **payload** itself

Satellite platforms examples (year)

Hubble Space Telescope (1990)

Disturbance: Thermo-mechanical energy stored and released in SA
Solution: Control system approach

James Webb Telescope (2021)



Disturbance: mainly the reaction weels
Solution: 2 Isolation stages + RW speed control

GOES 16 (2016)

Disturbance: RW´s and thrusters firings
Solution: 2 Isolation stages

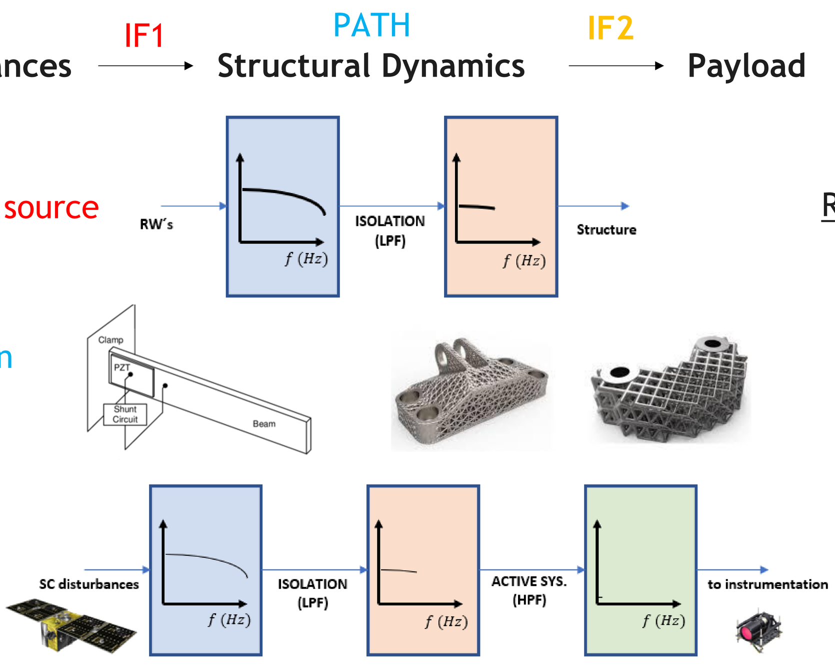
Disturbances → IF1 → PATH Structural Dynamics → IF2 → Payload

SOLUTIONS

Disturbance source — RW´s passive-active mounts — HF

Transmission path — Piezo, lattice struct… — HF

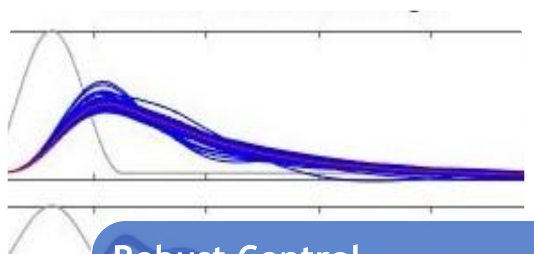
Payload IF — Isolation + Active Sys — LF+HF



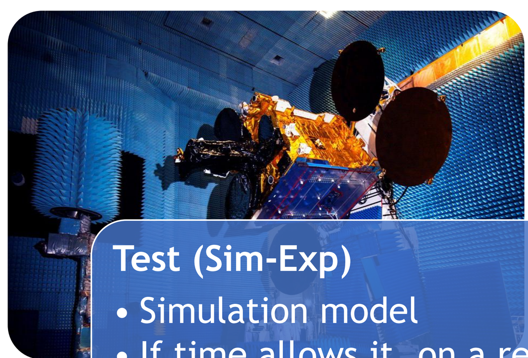
ROADMAP

Dynamics modelling
- AOCS Control System
- Flexible Multibody Dynamics
- Disturbances
- Y1

Architecture analysis
- AOCS coupling
- Mission objective-based
- Cost-effectiveness and performance
- Y2



Robust Control
- LPV
- Consider the main uncertainties present in the mechatronic system
- Y2-Y3



Test (Sim-Exp)
- Simulation model
- If time allows it, on a real cubesat benchmark
- Y4