5th IAA Conference on University Satellite Missions
and CubeSat Workshop

# STECCOsat: a laser ranged nanosatellite.

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# STECCOsat

**Mission description**

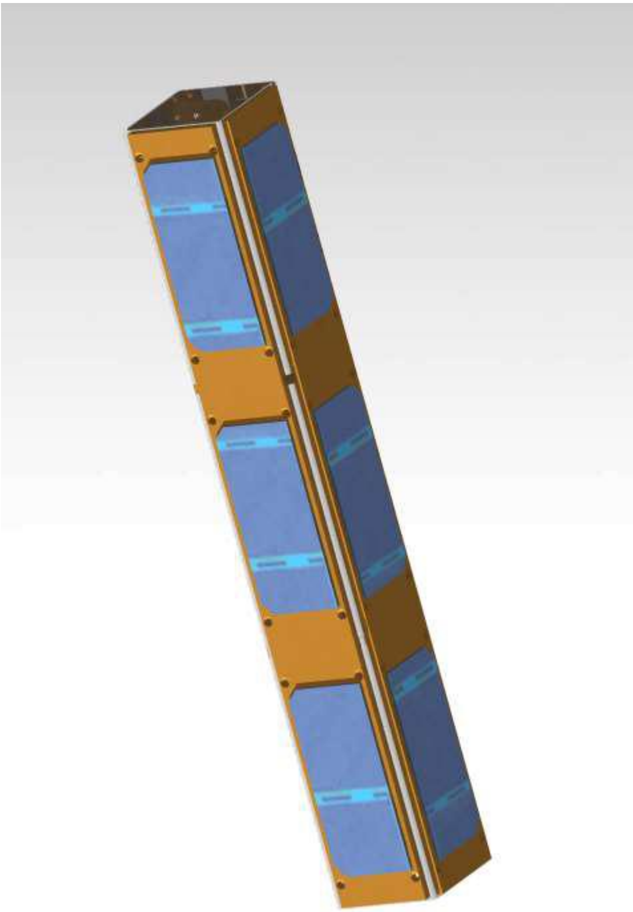
**Satellite (figure)**

**Payloads**

**Orbit**

**Attitude stabilization**

# STECCOsat



**STECCO**

Space Travelling Egg-Controlled Catadioptric Object

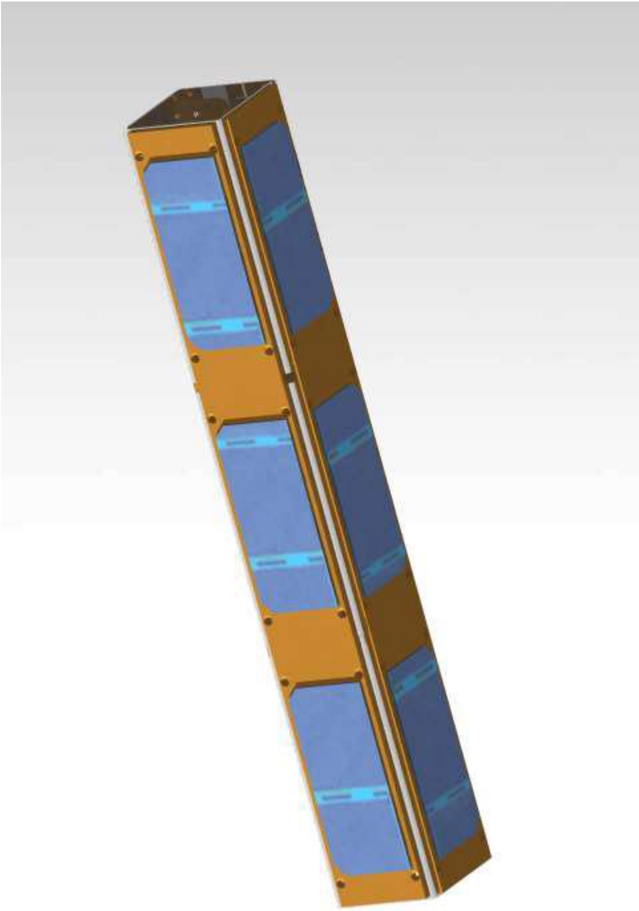
**6P PocketQube**

- Volume: 33x5x5 $cm^3$
- Mass:1 kg
- Max power:3.04 W

**Mission overview**

- Launch: Q3 2020 into UNISAT 7 by Gauss srl
- SSO orbit @ altitude of 400-600 km
- Orbit parameters considered for the analysis:
  - Inclination: 97.79 deg
  - Altitude: 570 km
  - Eccentricity: 0

# STECCOsat



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- Volume: 33x5x5 $cm^3$
- Mass:1 kg
- Max power:3.04 W

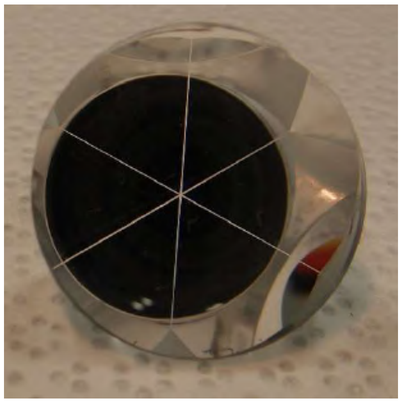
**Goals of the mission (payload)**

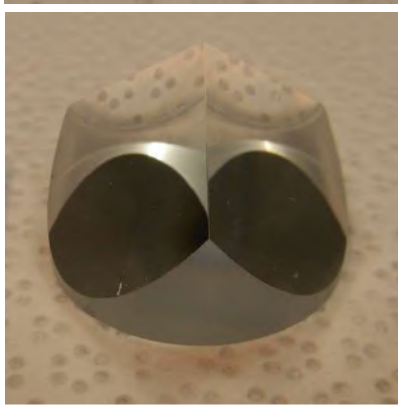
- Testing laser ranging capabilities on nanosats
- Testing innovative ADCS strategies and devices
    - Magnetometer-only attitude determination
    - Liquid reaction wheels
    - Passive viscous spin damper
- Validating SRAM based OBC for PocketQube

# STECCOsat

**Payload for Satellite Laser Ranging:**

**24.5 mm COTS cube corner reflectors.**





# Satellite Laser Ranging

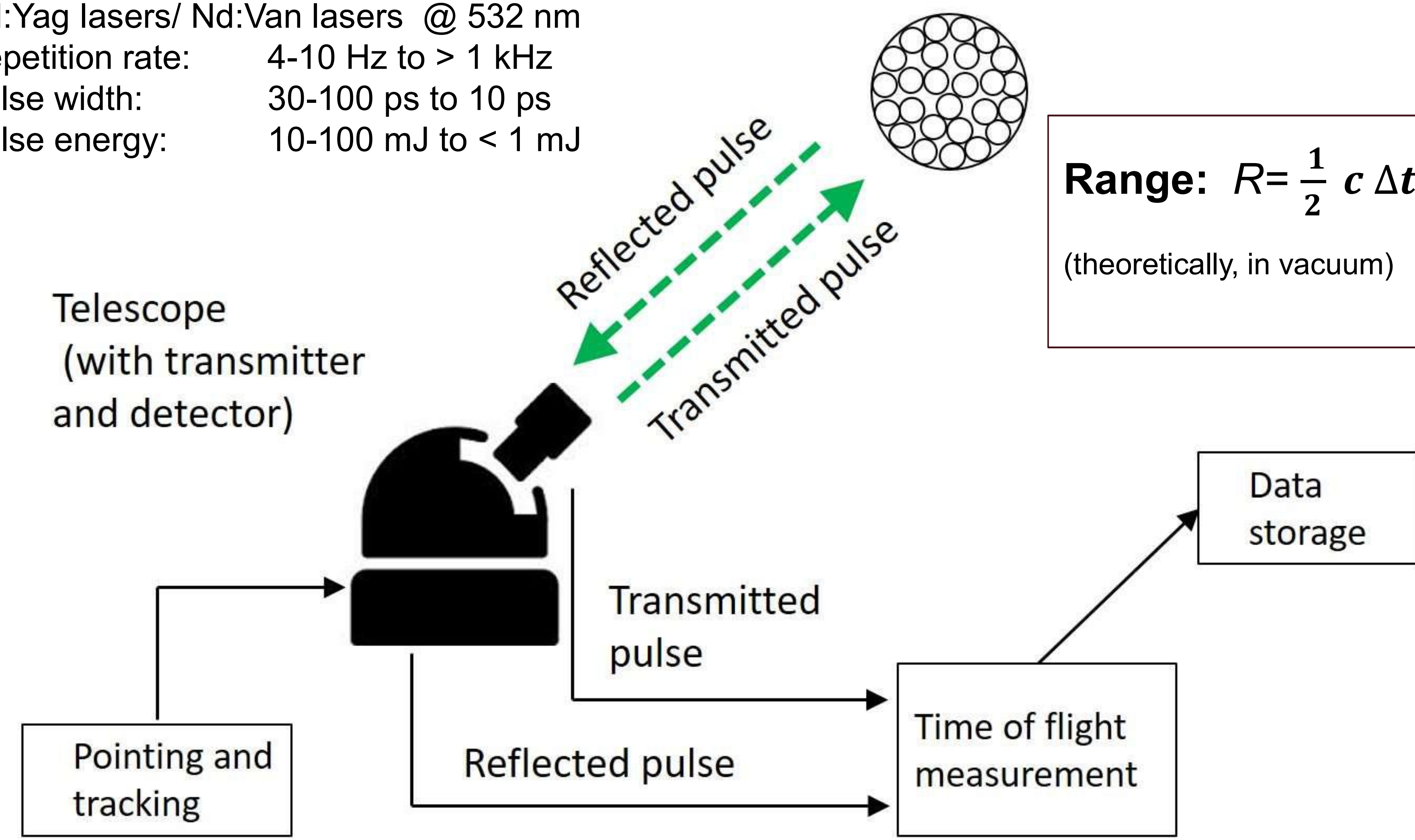
**Ground stations:**

Nd:Yag lasers/ Nd:Van lasers @ 532 nm

| | |
|---|---|
| Repetition rate: | 4-10 Hz to > 1 kHz |
| Pulse width: | 30-100 ps to 10 ps |
| Pulse energy: | 10-100 mJ to < 1 mJ |

**Range:** $R = \frac{1}{2}\, c\, \Delta t$

(theoretically, in vacuum)



# Laser Ranging

## Types of cube corner reflectors:

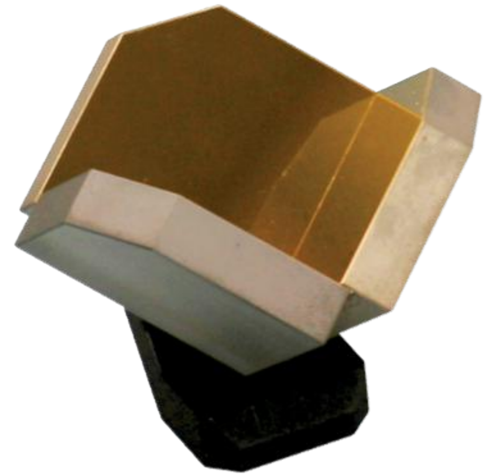
### Uncoated
(LAGEOS, LARES,…)

- Total internal reflection
- High reflectivity (r>0.9)
- Change polarization
- Cut-off angle (17° )

### Back-coated
(CHAMP, GRACE,…)


- Lower reflectivity (r<0.8)
- Maintain polarization
- No cut-off angle
- Coatings absorb heath

### Hollow

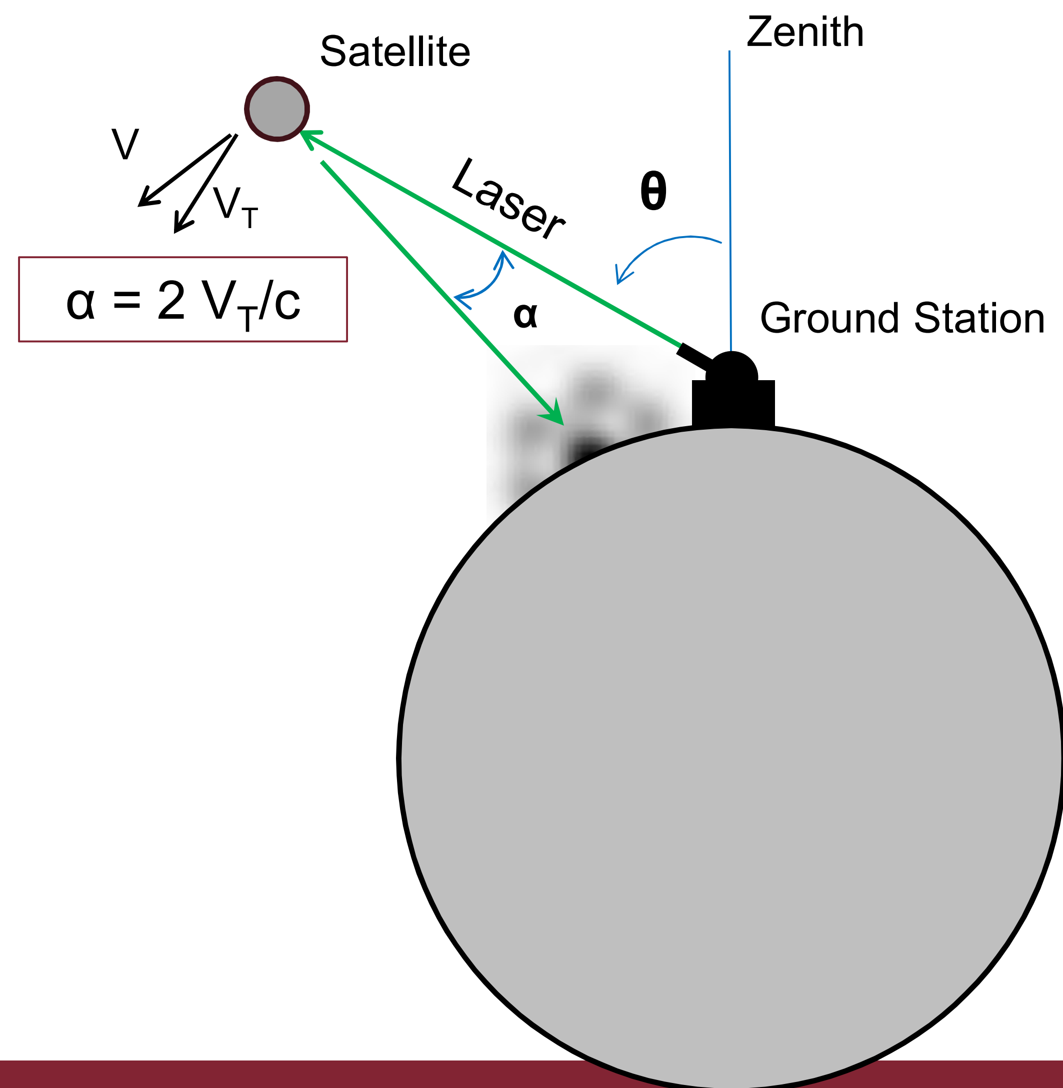


- Few tests in space
- Thermal problems at the joints

# Laser Ranging: Velocity Aberration

$\alpha := f(\theta, h_{sat})$

$\alpha_{min} \rightarrow \theta = 70°$ (EL = 20°)
$\alpha_{max} \rightarrow \theta = 0°$ (EL = 90°)



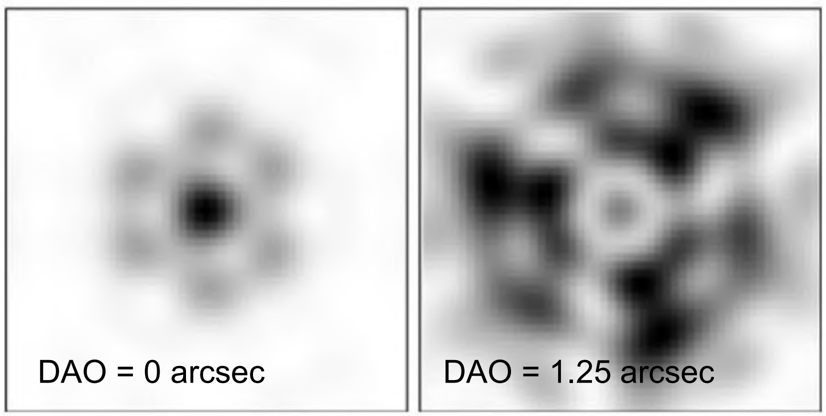

**Compensation of Velocity Aberration:**

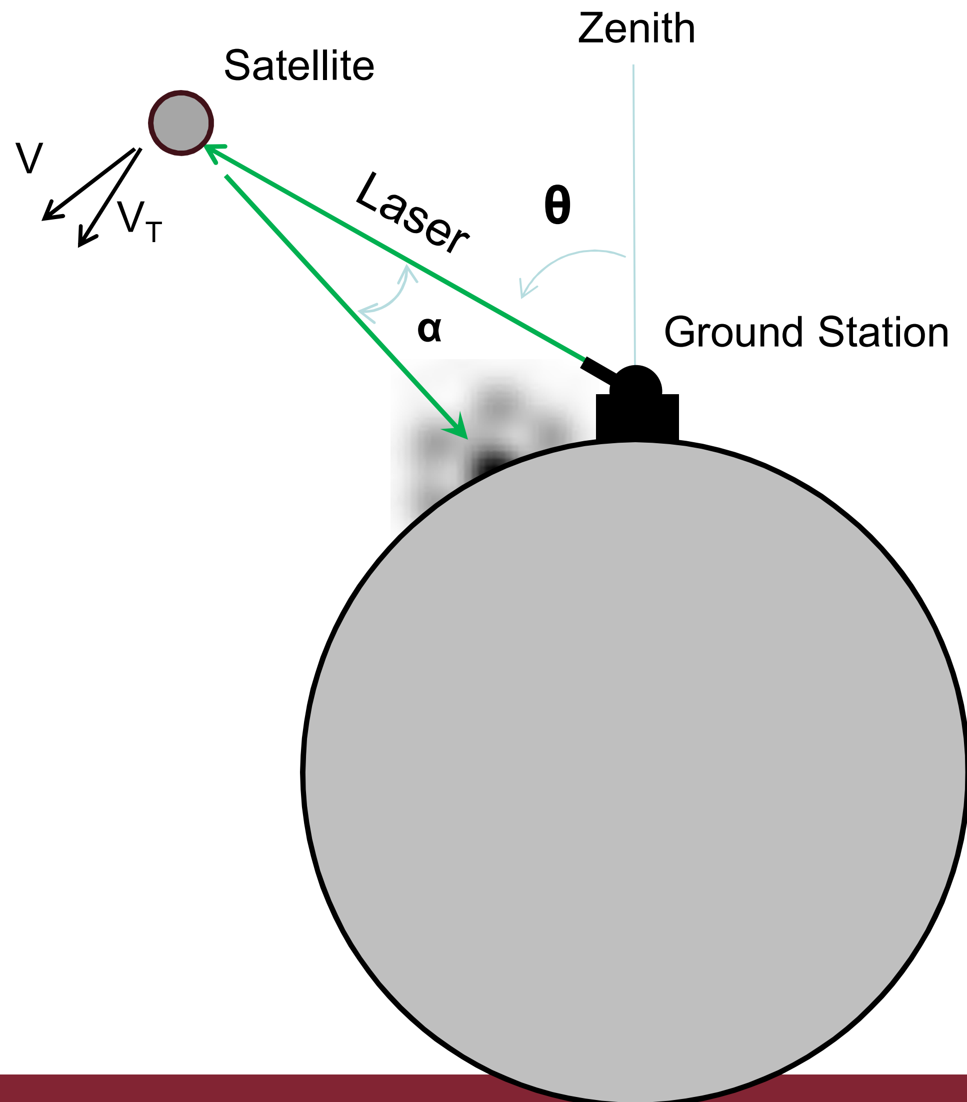
1. With Diedral Angle Offset
2. With smaller CCRs

# Laser Ranging: Velocity Aberration

**DAO: Dihedral Angle Offset.**

To spread the energy on the lateral lobes of the Far Field Diffraction Pattern



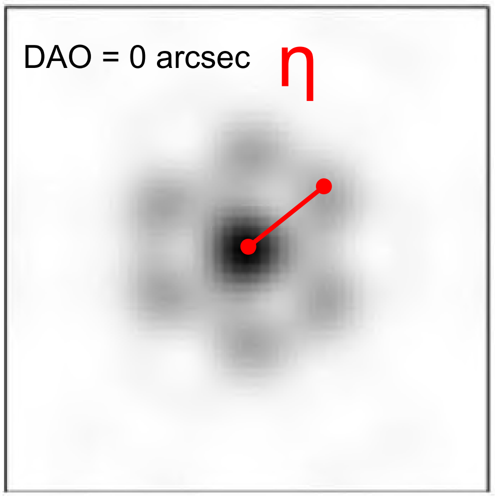



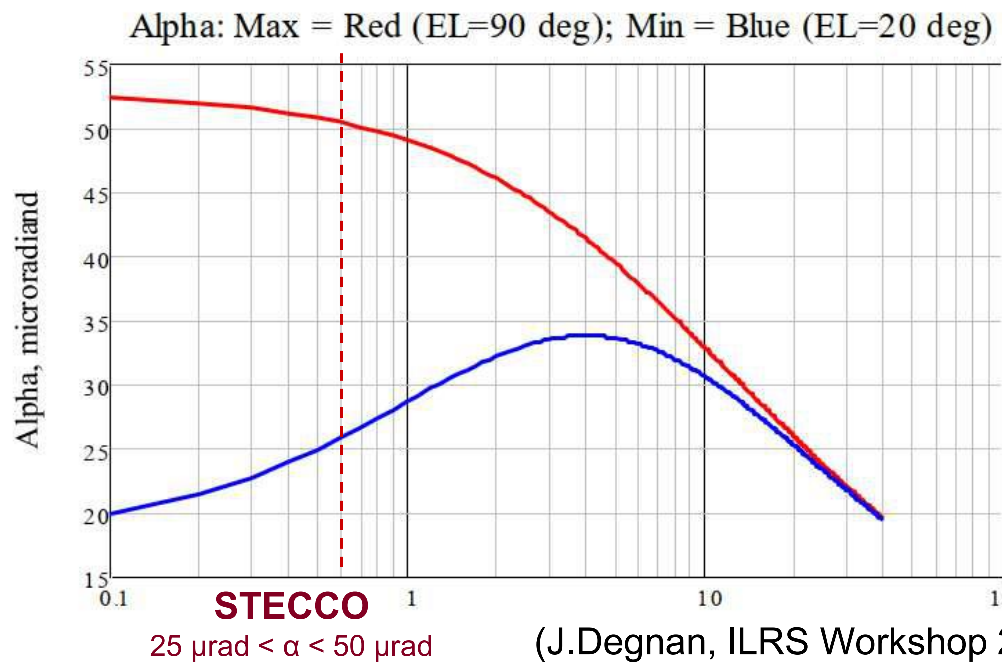

DAO correction possible with custom CCRs:

- Expensive;
- Longer procurement time

# Laser Ranging: Velocity Aberration

## Smaller CCRs




(J.Degnan, ILRS Workshop 2012)

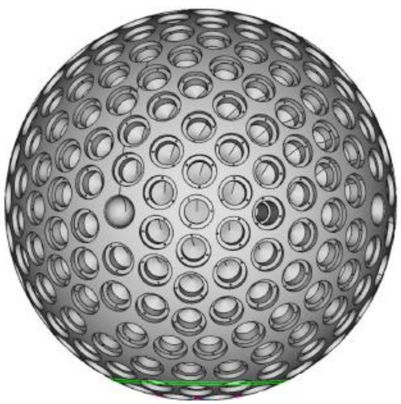
| | |
|---|---|
| CCR DIA. 38.1 mm (1.5'') | 17 μrad < η < 31 μrad |
| CCR DIA. 25.4 mm (1'') | 25 μrad < η < 47 μrad |

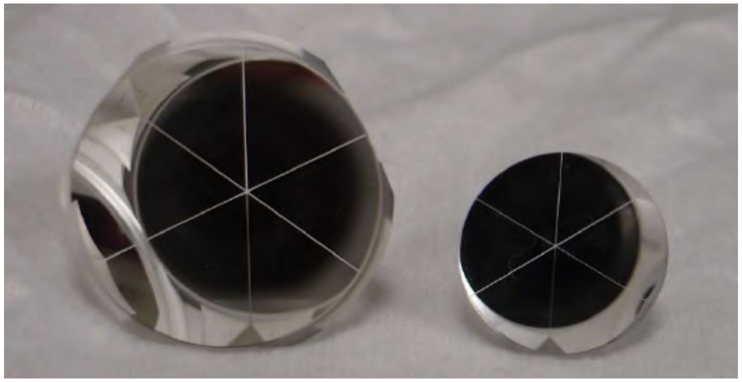
## Satellites with small CCRs

### Missions with Commercial Off-The-Shelf (COTS) small CCRs

**Technosat (Technische Universität Berlin)**
N. 14 CCRs DIA 10 mm
COTS units
Launch: 2017

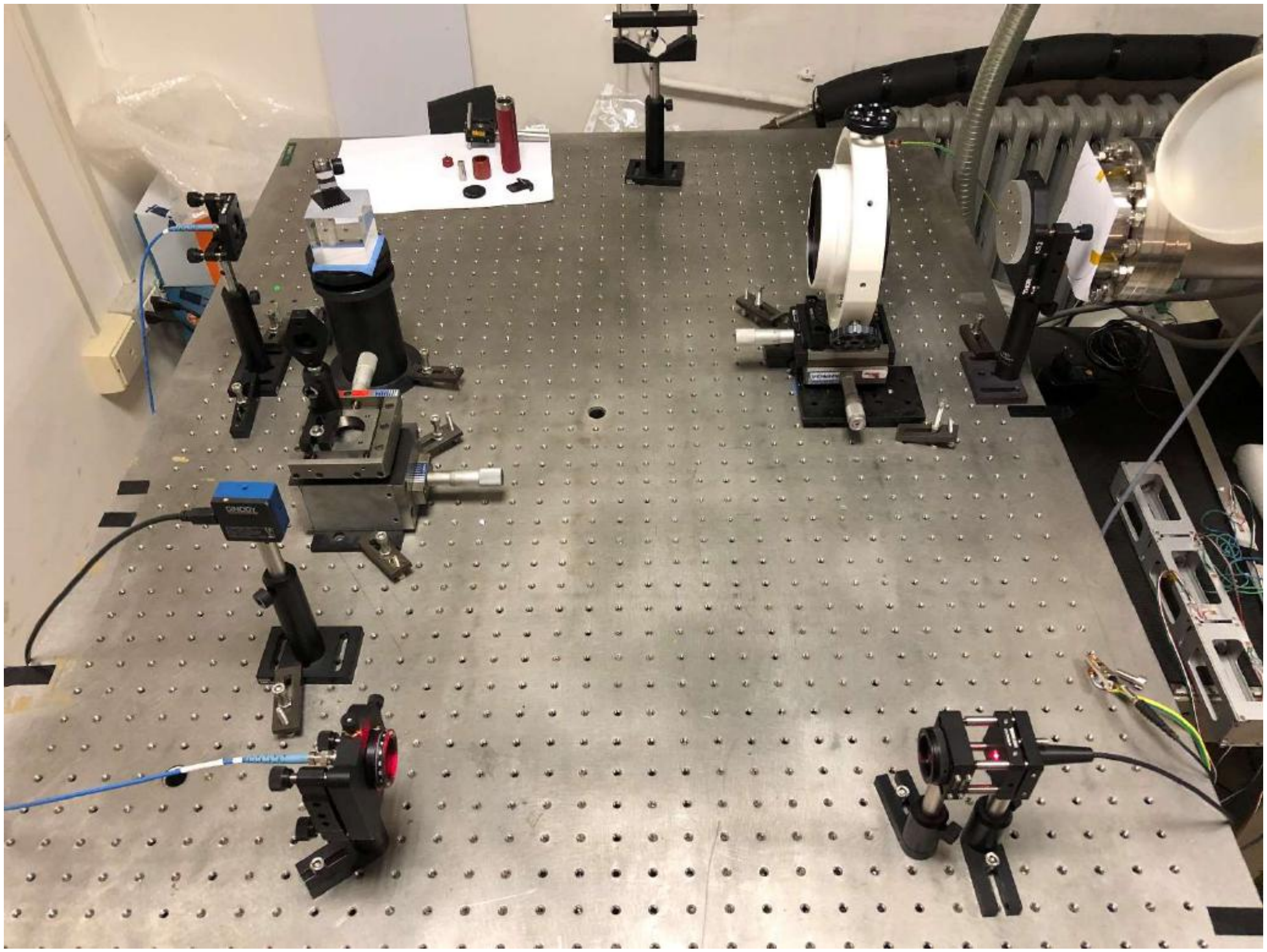
**LARES 2 (ASI)**
N. 303 CCRs DIA 25.4 mm
COTS units
Launch: 2020





# Characterization of STECCOsat CCRs

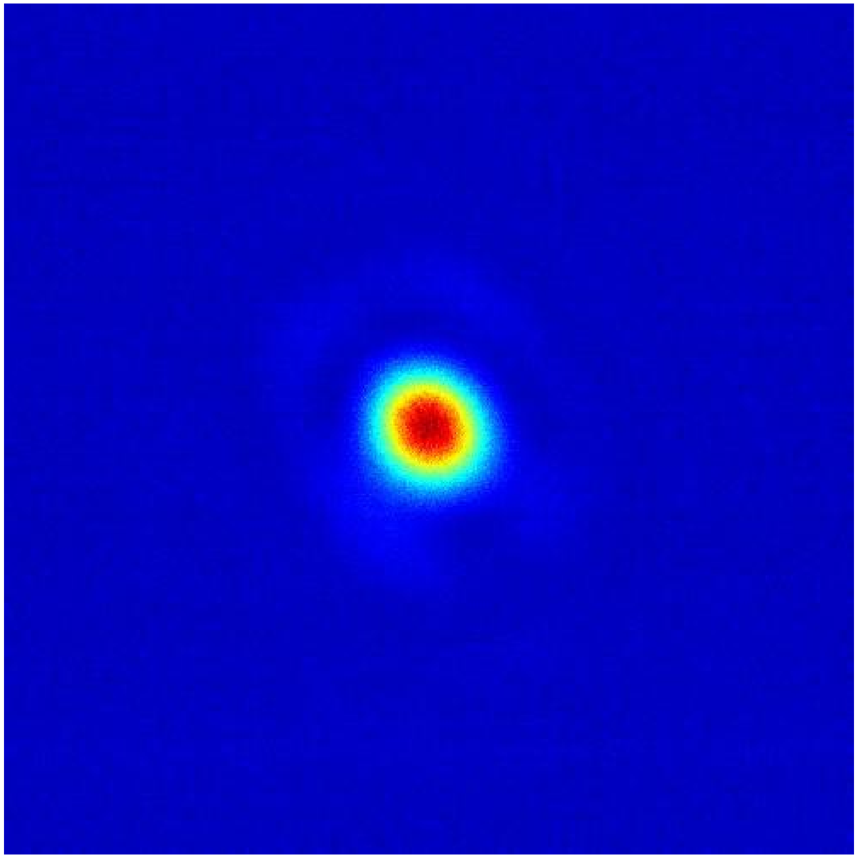
## FFDP characterization for attitude determination



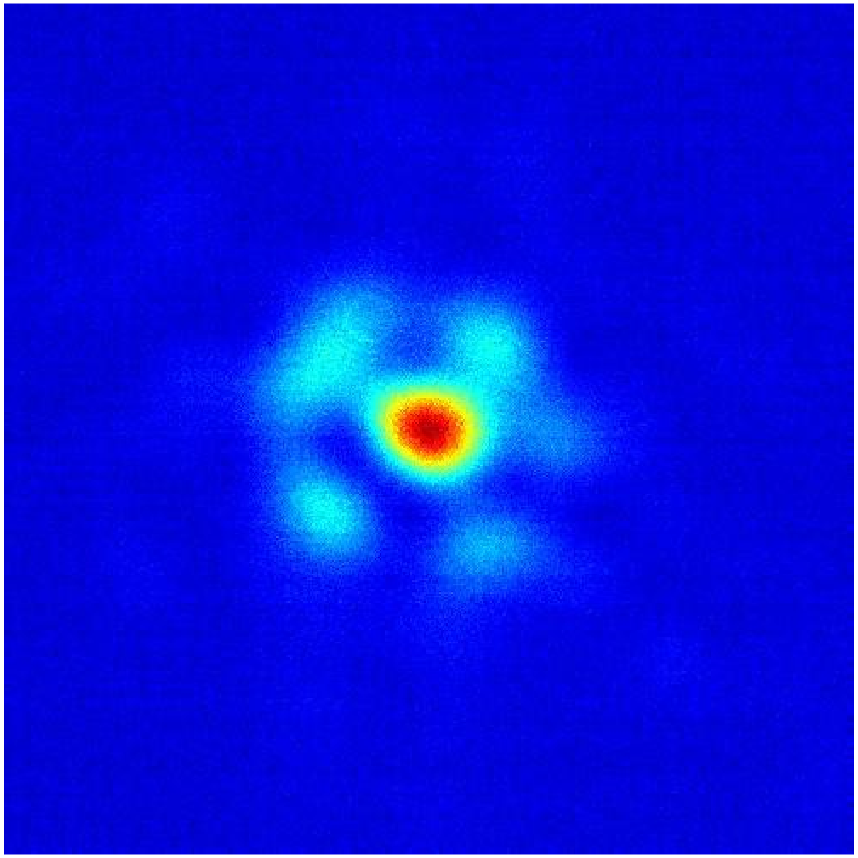
# Characterization of STECCOsat CCRs

## Preliminary FFDP acquisition

25.4 mm COTS coated



25.4 mm COTS uncoated

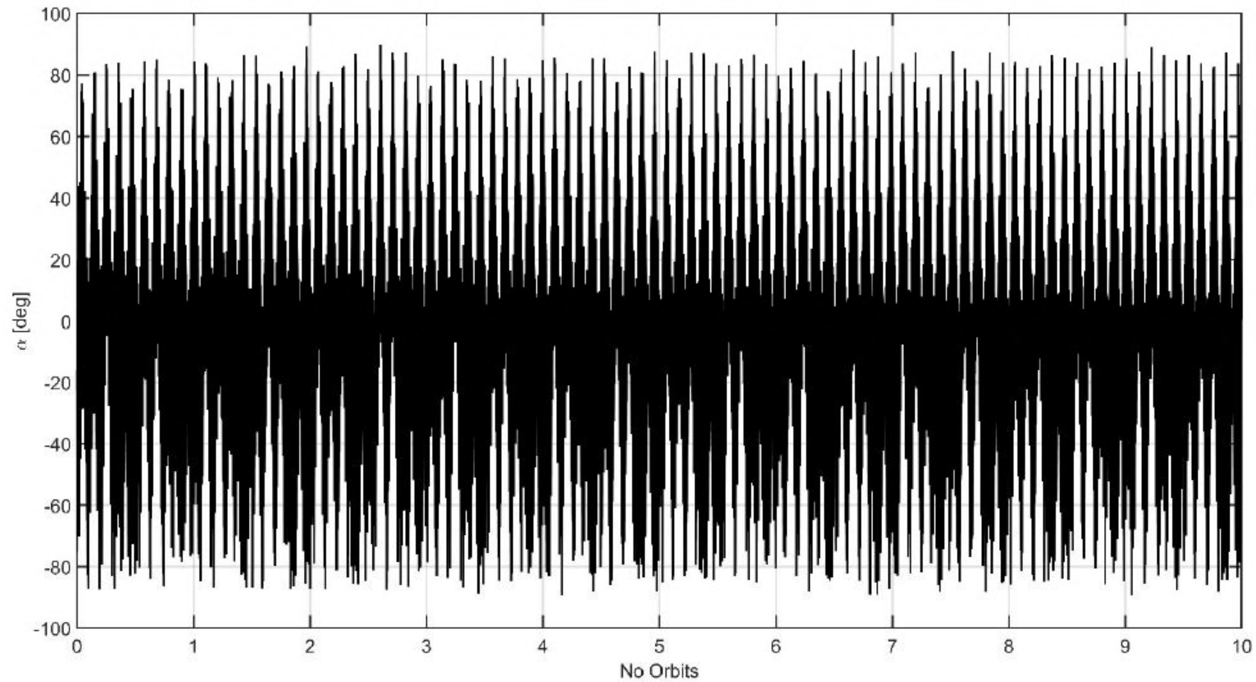


## Challenge: Evaluating attitude angle by laser ranging

### Gravity gradient torque

Beside liquid reaction wheels, which are a payload to be tested, STECCOsat attitude will not be controlled and evolve under the effect of gravity gradient torque

$$\vec{M} = 3\frac{\mu}{r_G^{\,3}}\hat{r}_G \wedge I\hat{r}_G$$

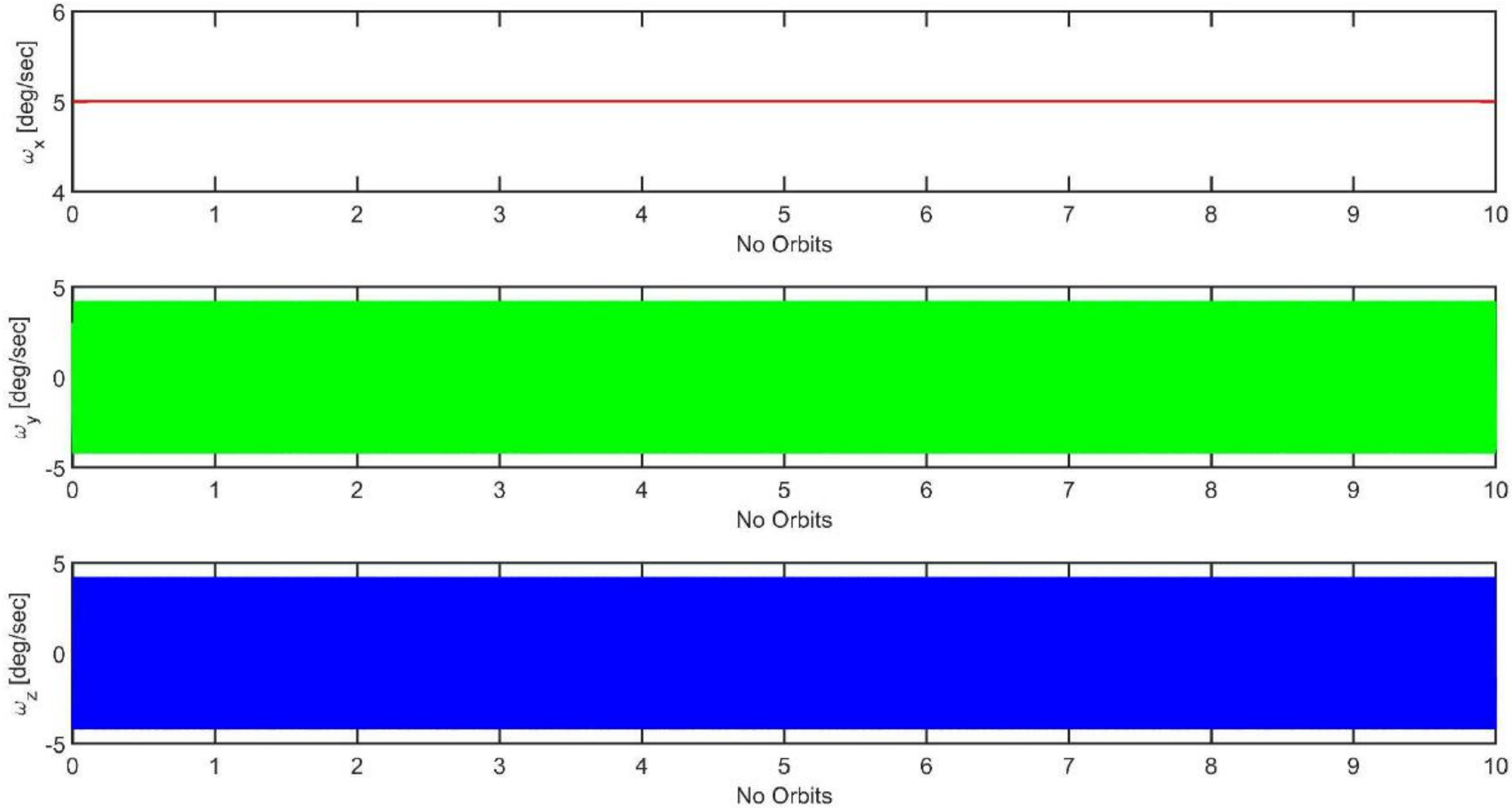



### Passive viscous damper stabilization

Because the natural damping torques acting on the satellite are negligible, a passive viscous damper was developed to reduce the initial angular rates (picture for **ω**=[5 3 -3] deg/sec)

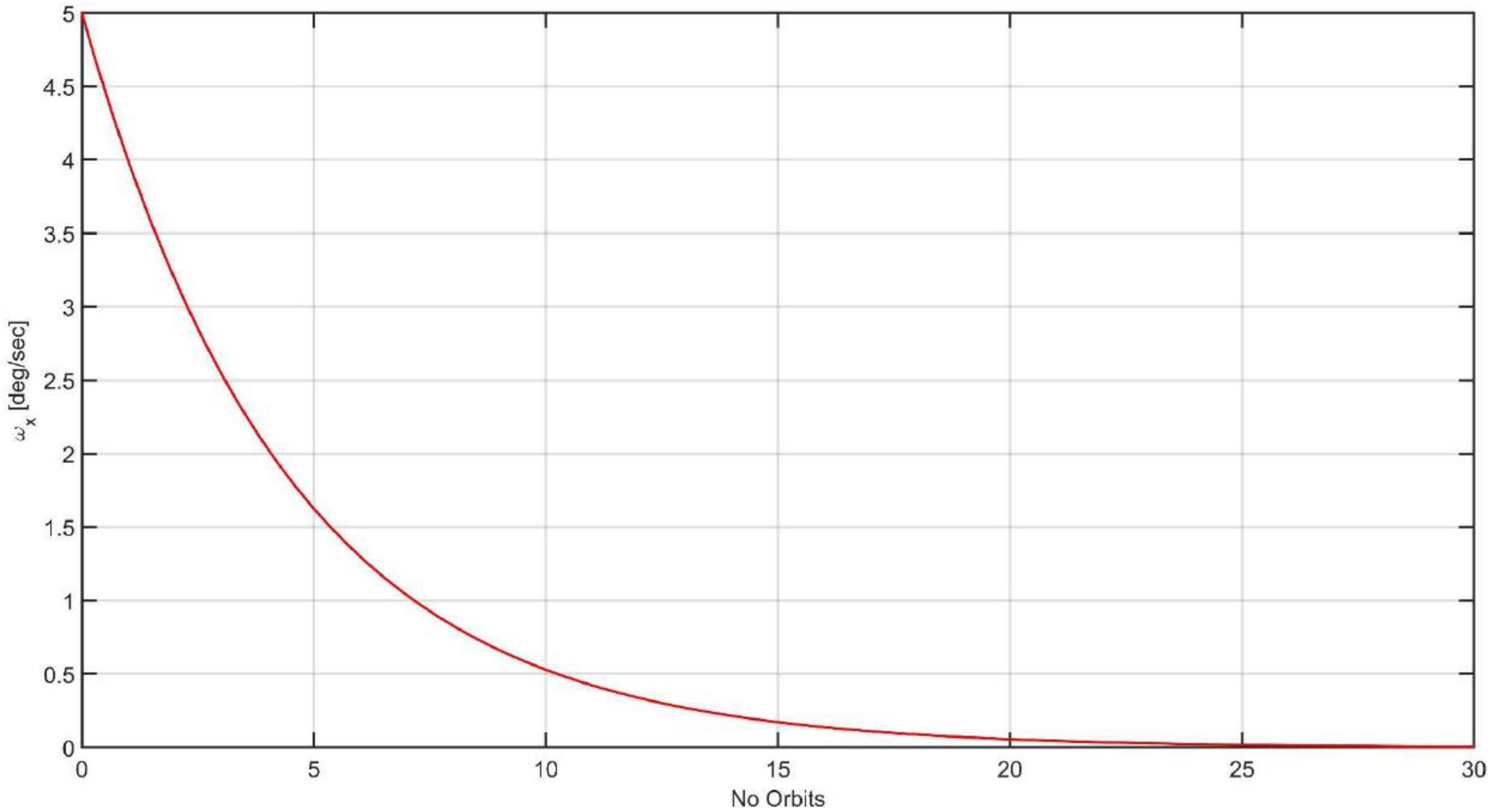
# Challenge: Evaluating attitude angle by laser ranging

**Without damper** (Aerodynamic and solar radiation pressure torques considered)



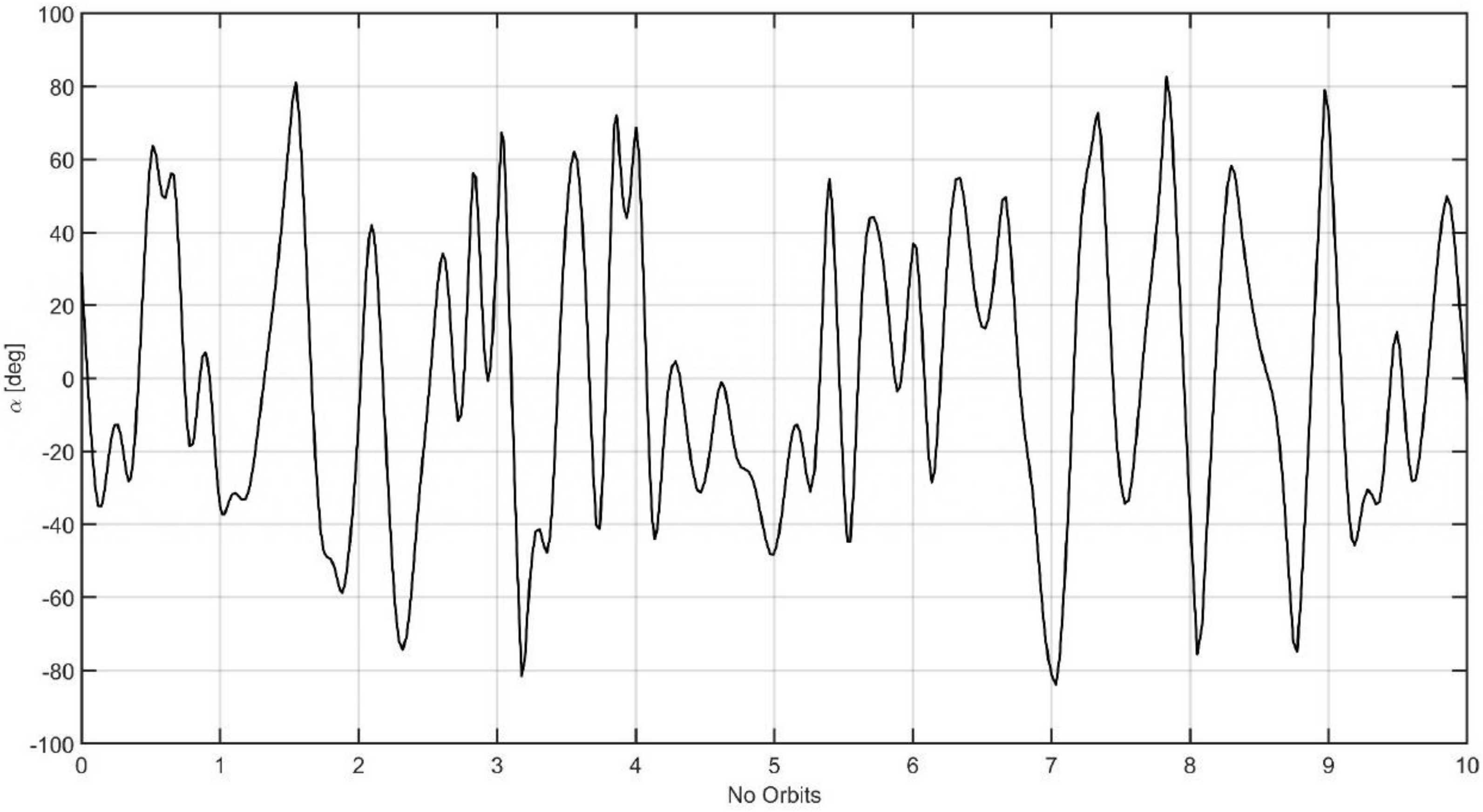
# Challenge: Evaluating attitude angle by laser ranging

**With damper** (example for $\omega_x$; similar behavior along the other axes)



# Challenge: Evaluating attitude angle by laser ranging

## Attitude motion with damping



# Conclusion

- STECCOsat is a 6P PocketQube satellite under development by the School of Aerospace Engineering of Sapienza University of Rome.
- STECCOsat attitude is controlled by gravity gradient torque and stabilized using a passive viscous damper.
- Once stabilized, the satellite will be tracked by satellite laser ranging.
- The satellite is equipped with two small, commercial CCRs.
- One CCR is a coated cube corner, the other one is an uncoated cube corner, to distinguish which face is nadir pointing.
- SLR will provide a measure of the attitude motion.
- FFDP characterization and experimental tests are being performed.