FISICA
Far Infrared Space Interferometer Critical Assessment
Science Goals of a Sub-arcsecond Far-infrared Space Observatory

FISICA: engineering problems and system requirements for interferometric observations from the space

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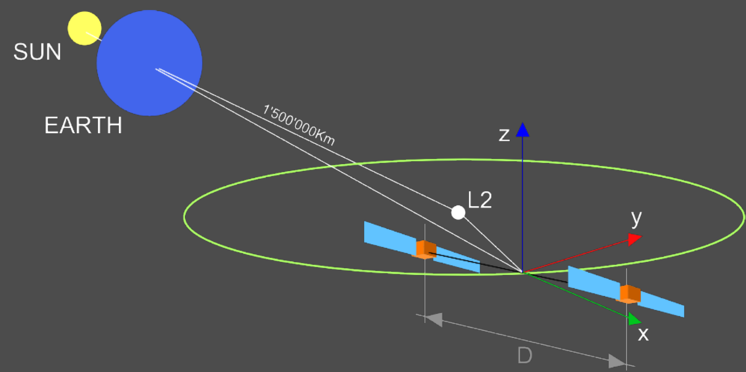
INTRODUCTION

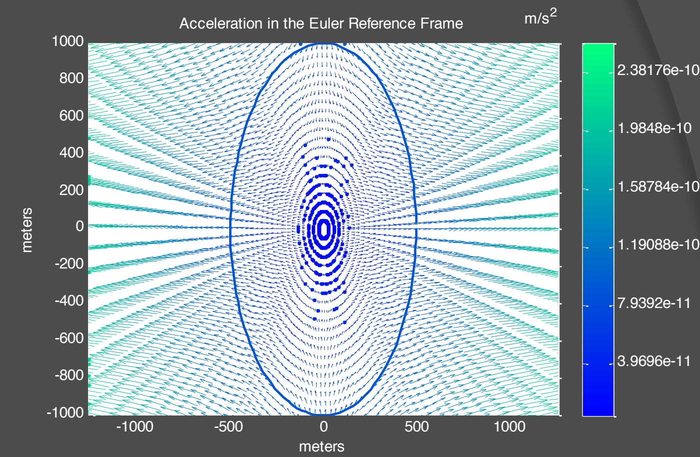
In this talk will be analyzed some technological problems related to the interferometer development, with particular emphasis in the possible use of accelerometers on board of the satellites that seems to offer the following opportunity:

- to implement a control loop algorithms to keep the satellites in the appropriate positions during the observation time required to cover all the *u,v* plane, for each single source
- to permit to measure the level of vibrational noise presents on them.

The heritage for these activities comes from the developments of the ISA (Italian Spring Accelerometer) an accelerometer conceived for the BepiColombo an ESA Cornerstone mission for the exploration of Mercury and to test the General Relativity.

GRAVITY GRADIENTS ACTING ON THE TELECOPE IN L2

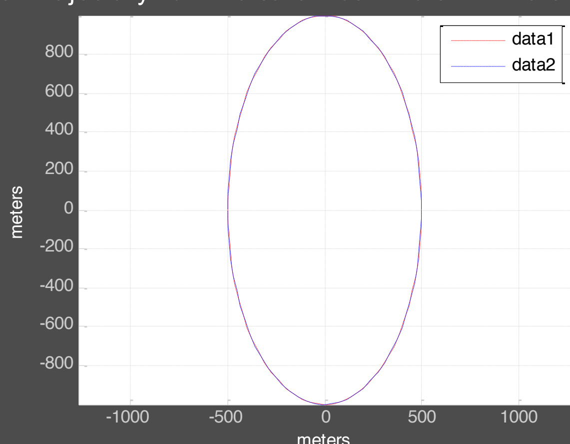


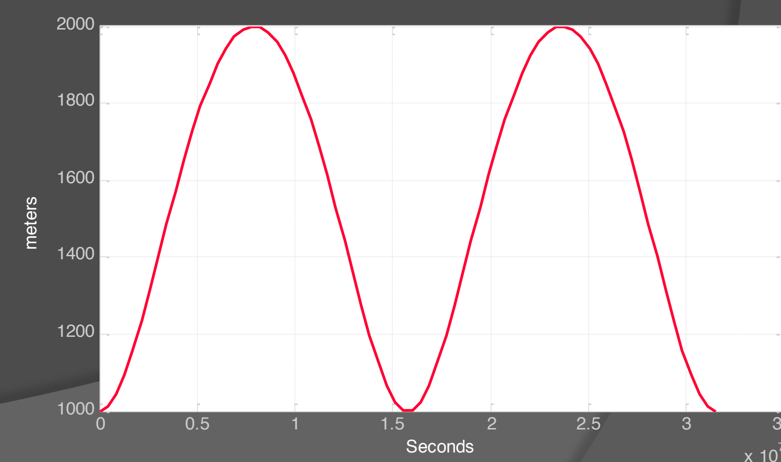


$\rho + 2\omega_0 \times \rho + \omega_0 \times \rho + \omega_0 \times (\omega_0 \times \rho) = G \cdot \rho$

Accelerations in the Euler reference frame in L2, due to the gravity gradient.

Orbital Trajectory for two satellites in Euler-Hill reference frame

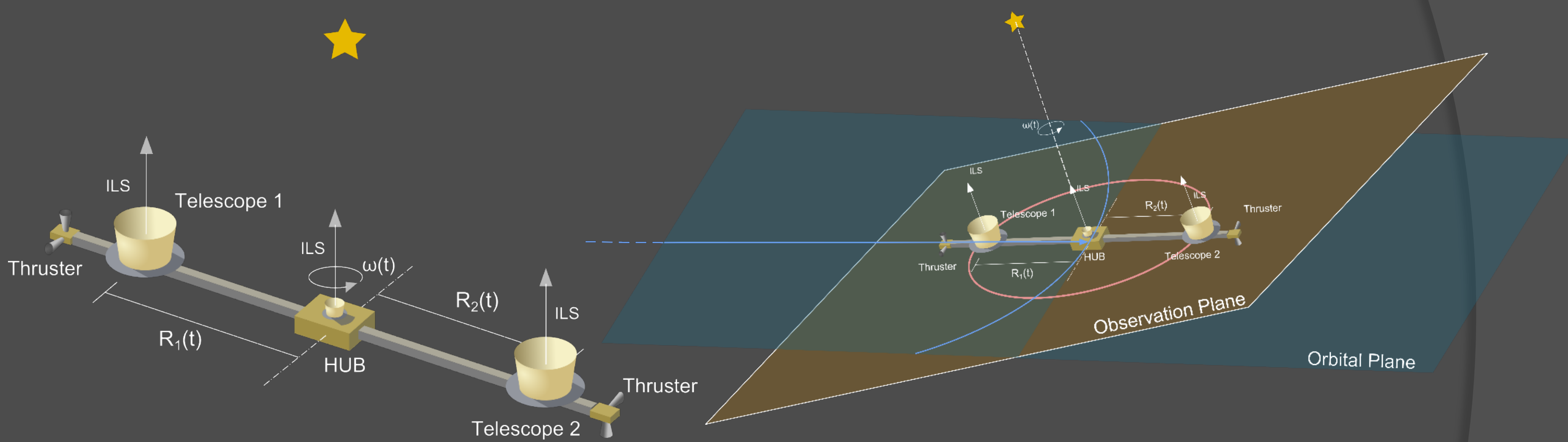




Two satellites out of phase by 180 ° in a Euler non-inertial reference frame.

Relative distance between the two satellites

DYNAMIC ACCELERATIONS ACTING ON THE TELESCOPE

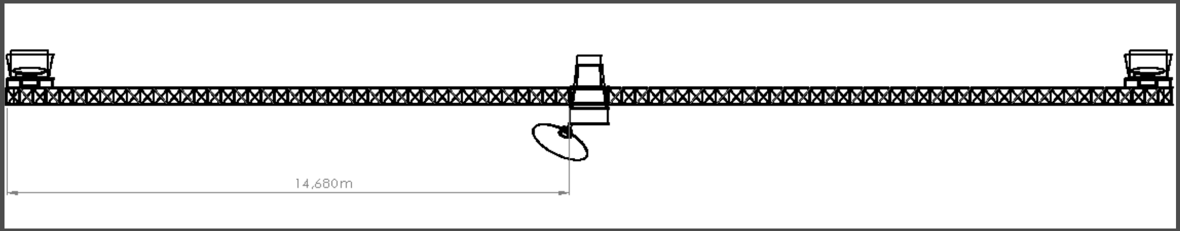


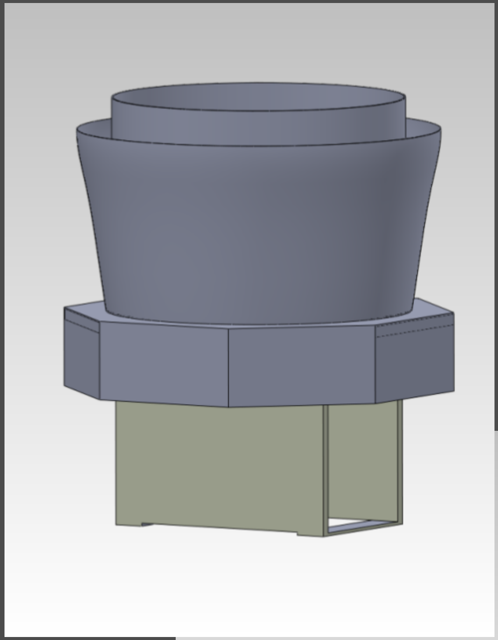
$$a=(\nabla\cdot g)R-\omega\times(\omega\times R)-\omega\times R-2\omega\times v-A_{NGP}-\Delta V/\Delta t|_{Man}$$

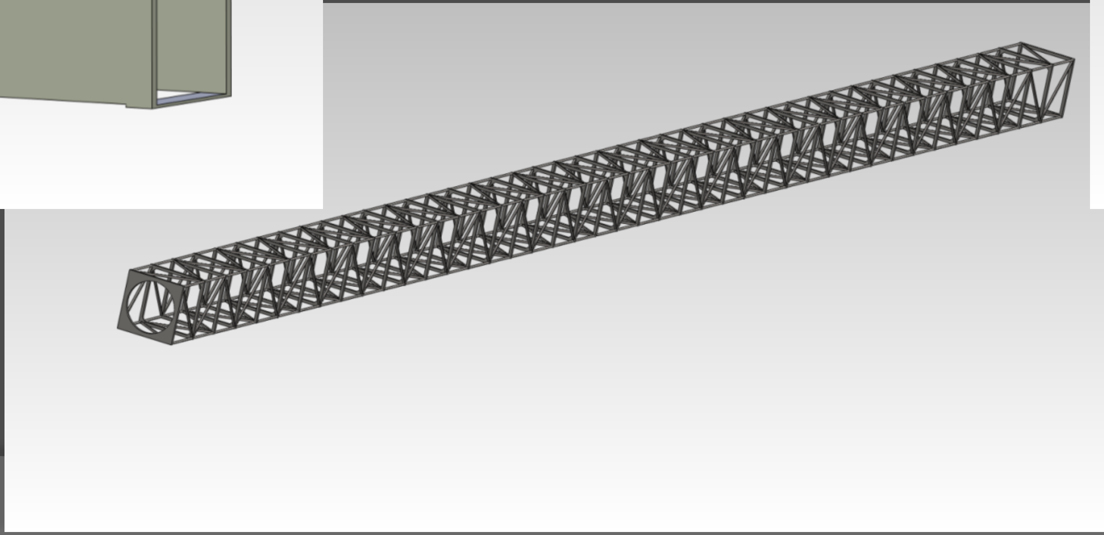
1. Accelerations due to gravity gradients
2. Apparent accelerations
3. Non–gravitational accelerations (NGA),
4. Accelerations due to thruster maneuvers

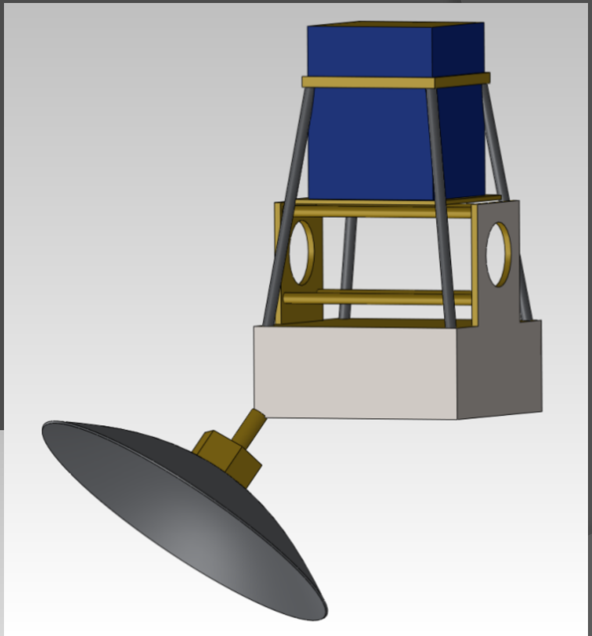
Free-flyer
Tethered
Rigid Structure

TELESCOPE NORMAL MODES

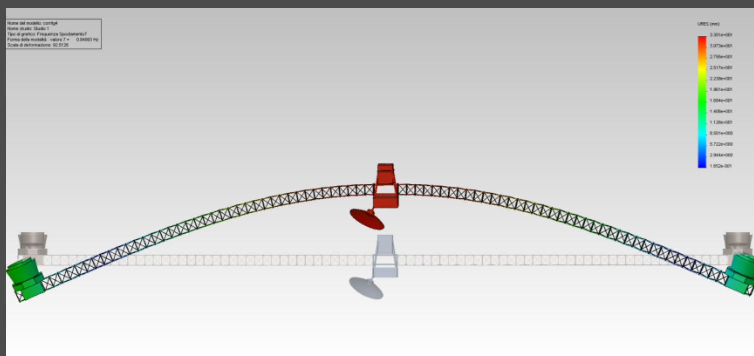


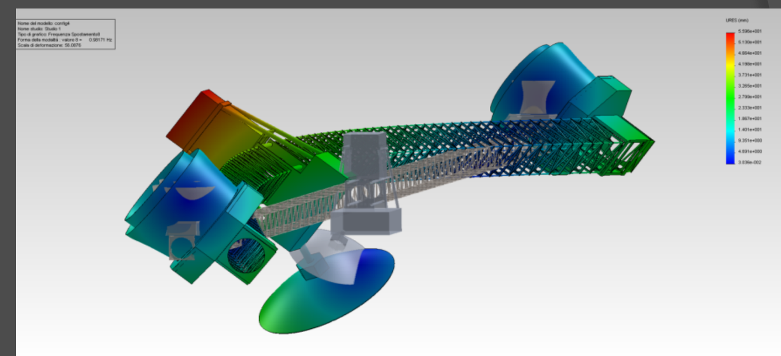


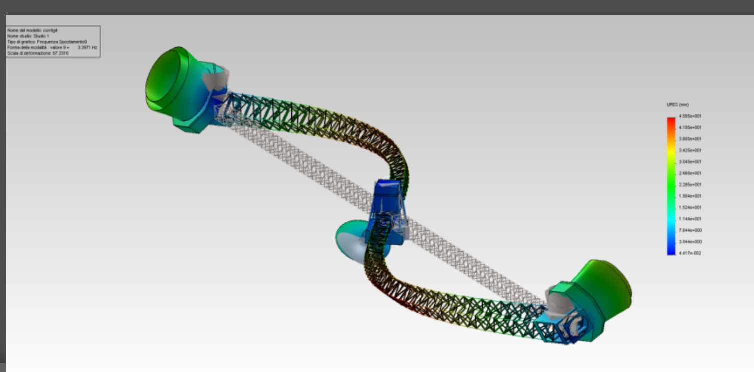


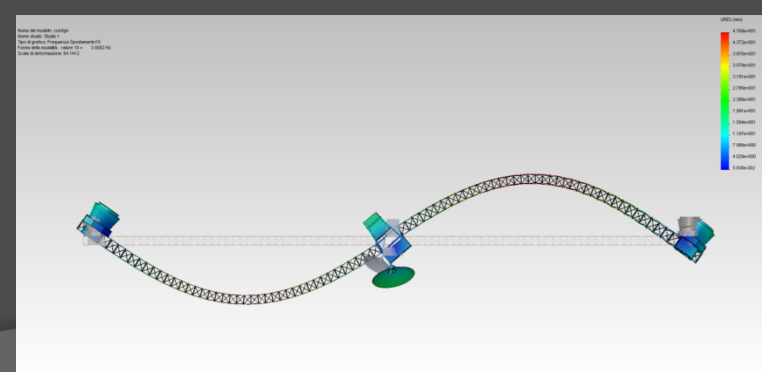


TELESCOPE NORMAL MODES



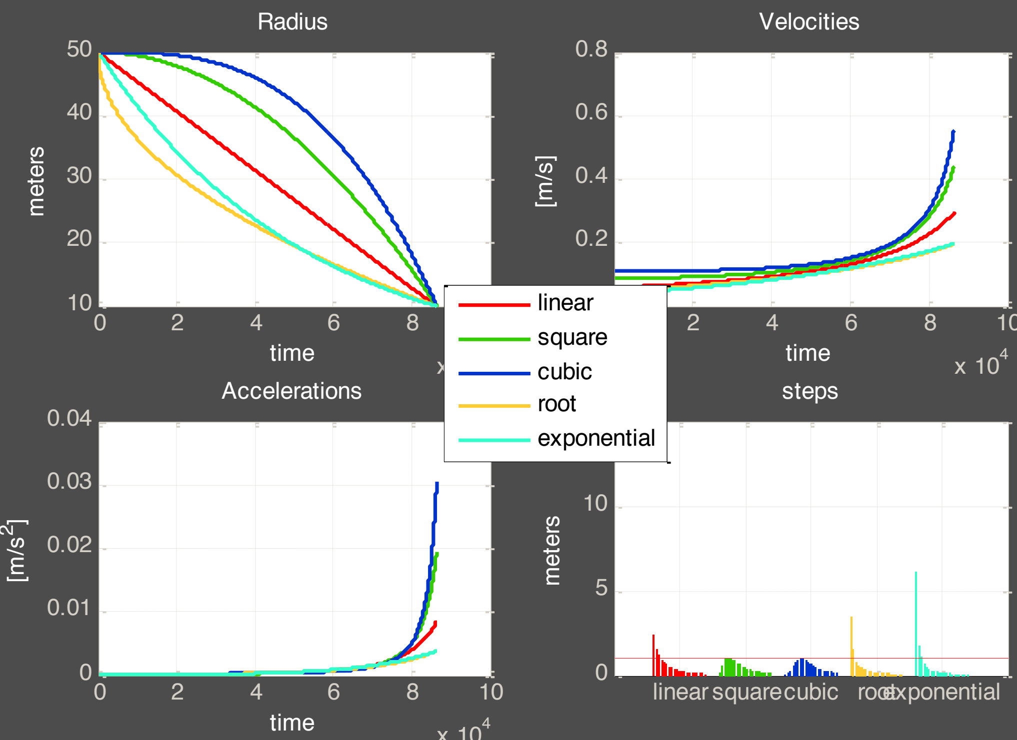


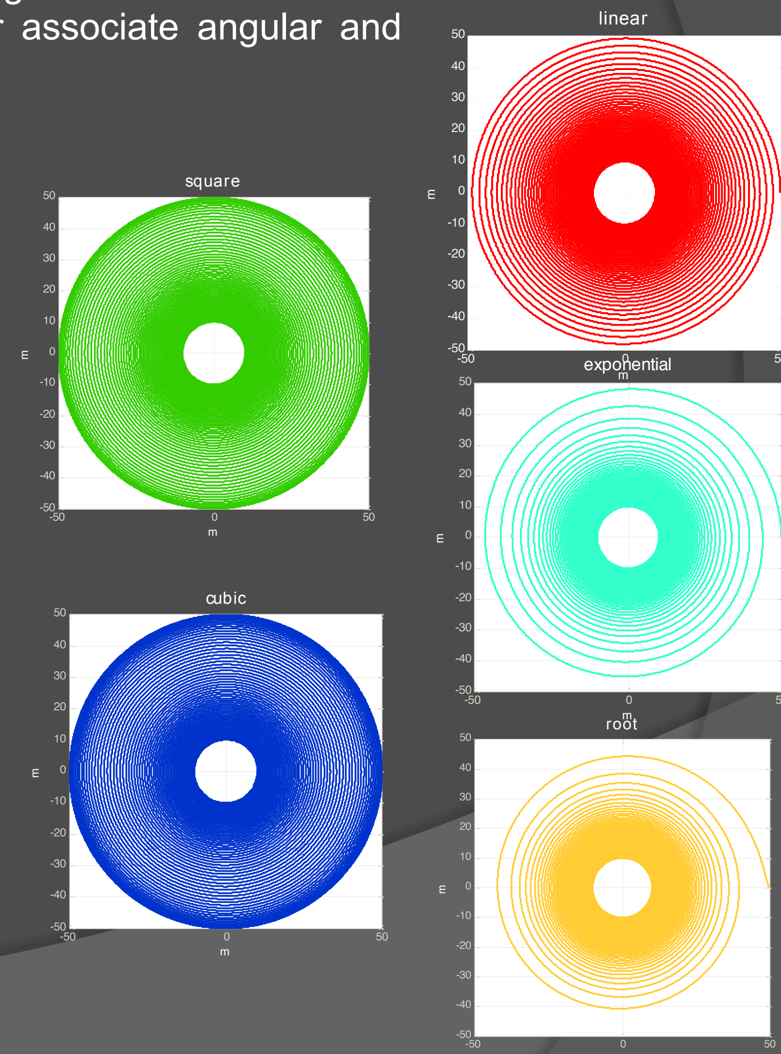




UV SCANNING PROCEDURES WITHOUT THE USE OF THRUSTERS

Due to the conservation of the angular momentum, a change in the radial distance of interferometer telescopes results in a change of their associate angular and tangential velocity

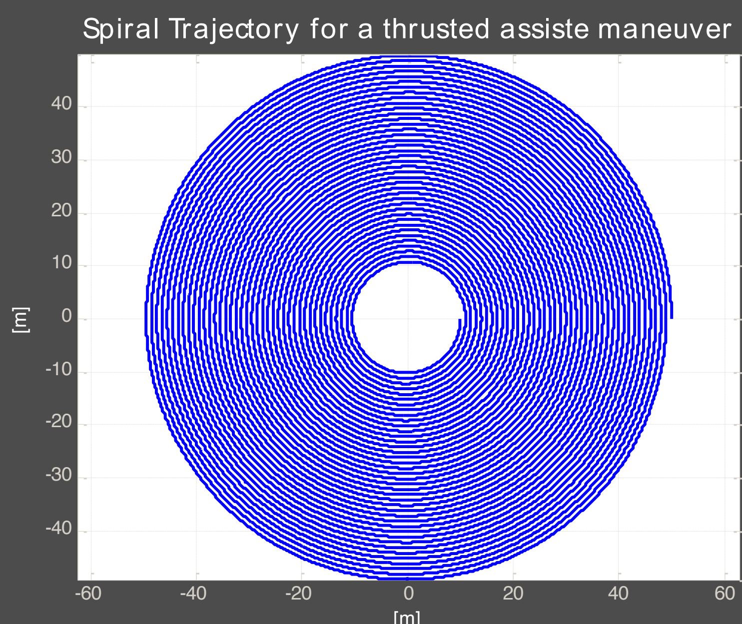


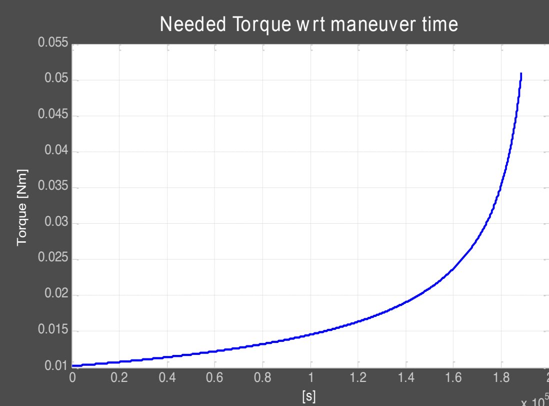


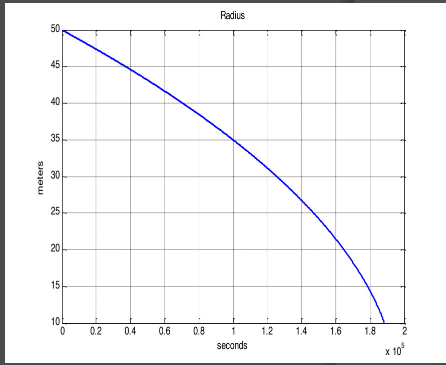
The five trajectories. In red linear law, in green the square, in blue the cubic, in yellow the square-root and in cyan the exponential one.

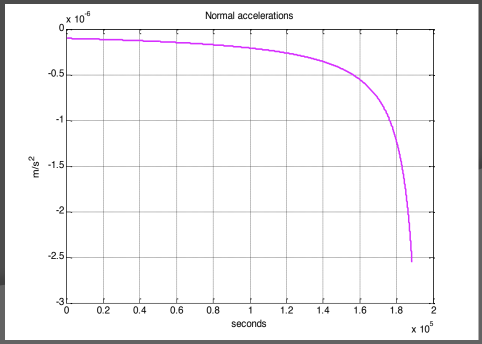
UV SCANNING PROCEDURES WITH THE USE OF THRUSTERS 1/2

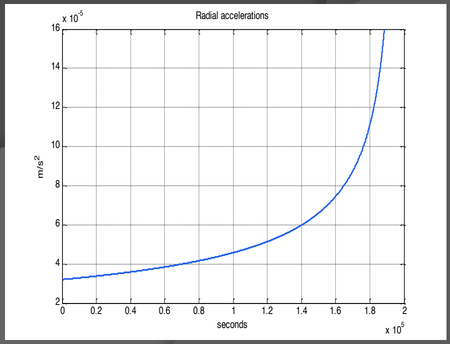
In order to have a constant tangential velocity along a spiral trajectory, the system should change its angular momentum continuously during the manoeuvres whit the use of thrusters.



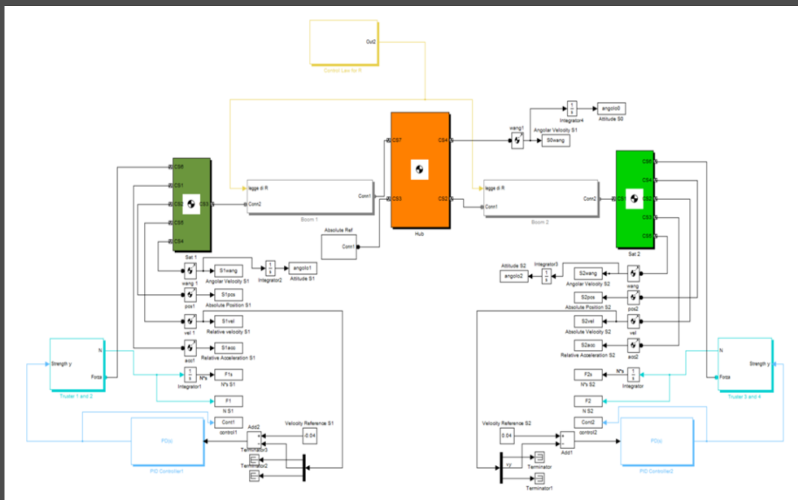


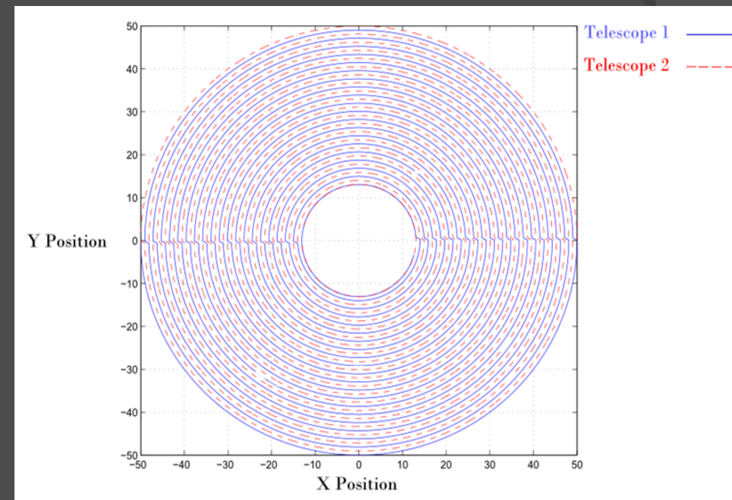


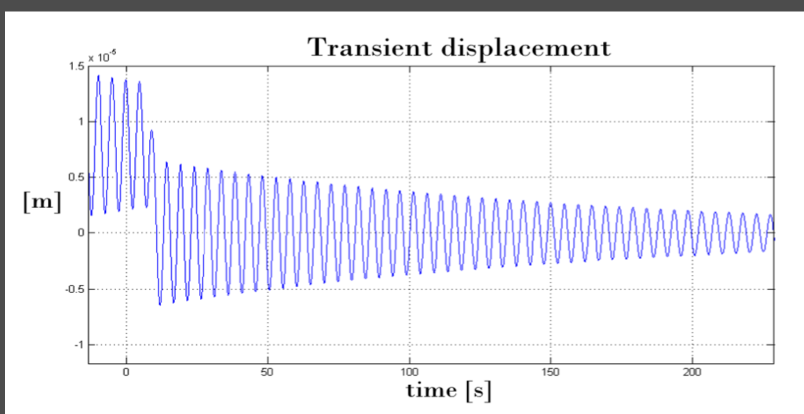


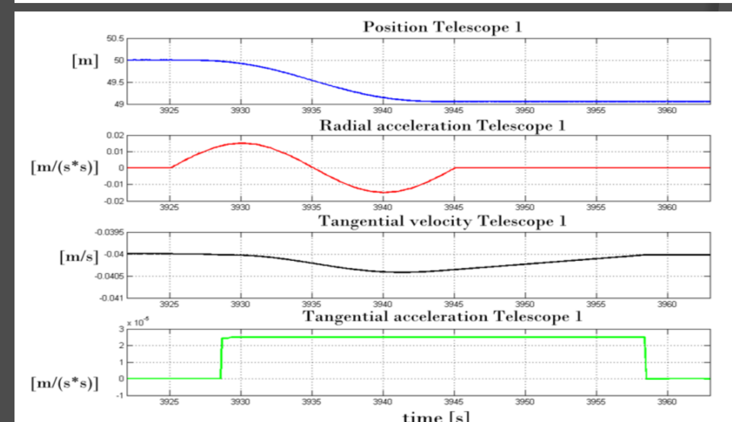


UV SCANNING PROCEDURES WITH THE USE OF THRUSTERS 2/2









Simulation of the process of scanning of the *uv* plane with radial movements of the telescopes of 1m after every rotation 180° of the interferometer.

ACCELERATION RANGE OF FREQUENCIES

Interferometer Band of measure (Science Light)

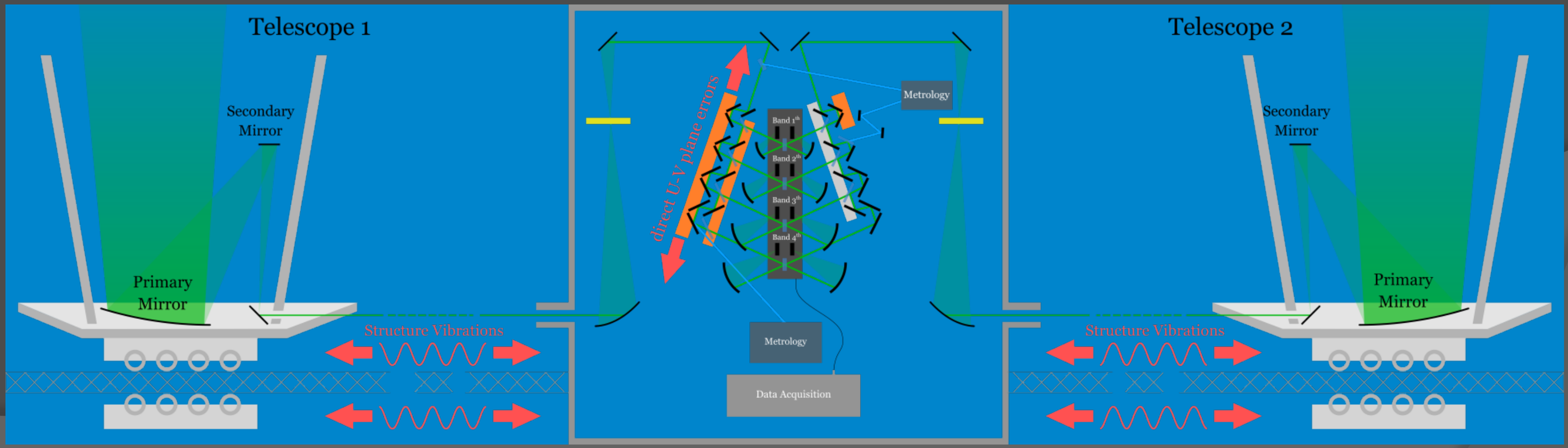
$$Band: [\lambda_{min} \;\; \lambda_{max}] = [25\ \mu m \;\; 500 \mu m]$$

If it is decided that the max distance related to the largest wavelength is performed by the ODL in 26 s, it follows a speed equal to:

$$Vs = 500 \cdot \frac{10^{-6}}{26} = 1.9 \cdot 10^{-5} m/s$$

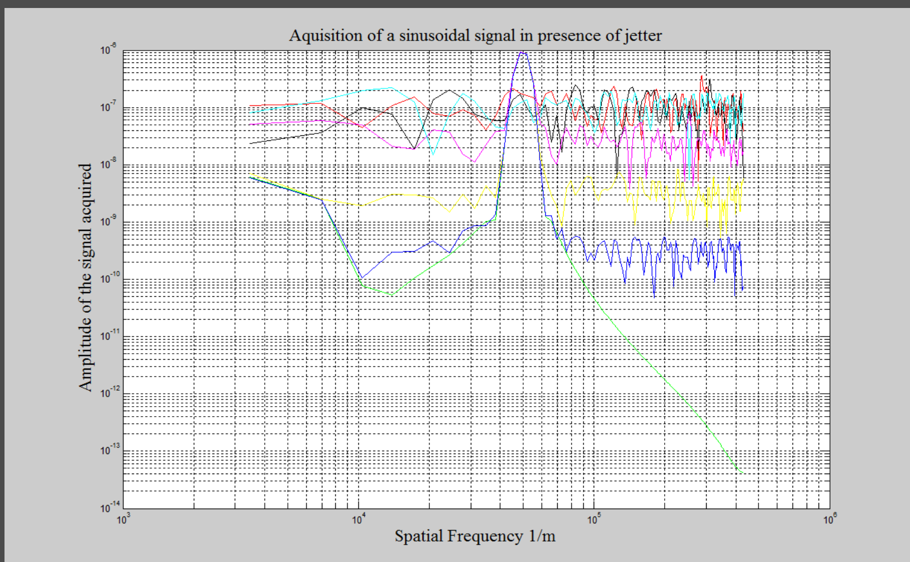
From this condition the frequency band in which we are working is:

$$Band: [f_{max} \;\; f_{min}] = [V_s/\lambda_{min} \;\; V_s/\lambda_{max}] = [6.4 \cdot 10^{-1} Hz \quad 3.8 \cdot 10^{-2} Hz]$$



SIMULATIONS CONCERNING THE ACQUISITION OF A INTERFEROMETRIC SIGNAL $I=I(\lambda)$ N PRESENCE OF JITTER NOISE.

$$I(\lambda)=I_0 \cdot\cos\left(2\cdot\pi/L_s\cdot(V_0\cdot t+x_b)\right)$$



I_0	10^{-6}
L_0	$500\ \mu m$
t_0	$26\ s$
$V_0 = L_0/t_0$	$1.9\cdot10^{-5}\ m/s$
L_s	$1/5\cdot10^{4} = 20\cdot10^{-6}$
x_b	$10^{-3}\ m/\sqrt{Hz} - 10^{-11}\ m/\sqrt{Hz}$ -

Results of a simulation relative to the acquisition of an interferometric signal considered as simple sinusoid, in the case of the parameter reported in the previous table. The level of white noise considered for the displacement is 10^-6 m/sqr(Hz) black; 10^-8 m/sqr(Hz) Ciano, 10^-9 m/sqr(Hz) Magenta, 10^-10 yellow, 10^-11 m/sqr(Hz) blue. Green represent the fft of the sinusoid acquired without jitter noise.

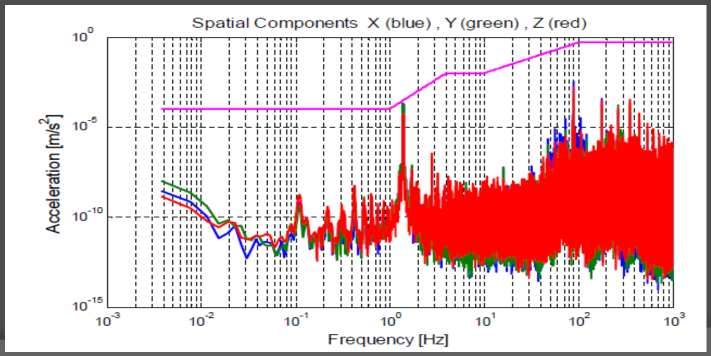
ANALYSIS OF THE SATELLITES VIBRATIONAL NOISE BC-MPO AS REFERENCES

$Band: [f_{max}\ \ f_{min}]=[V_s/\lambda_{min}\ \ V_s/\lambda_{max}]=[26/30\mu - 26/500\mu = [6.4\cdot 10^{-1}\ Hz\ \ 3.8\cdot 10^{-2}\ Hz]$

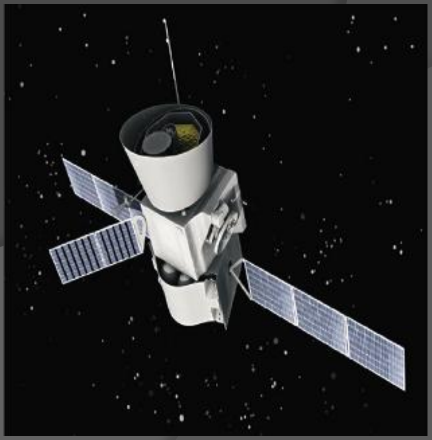
Vibrational noise inside the frequency measurements band on board the MPO (Mercury Planetary Orbiter) BepiColombo Mission for the RSE (Radio Science Experiments)

Frequency Hz	$3\cdot 10^{-5}$	$10^{-4} - 10^{-3}$	10^{-1}
Acceleration values (m/s^2)	$3\cdot 10^{-9}$	$10^{-9} - 10^{-9}$	10^{-4}
Corresponding displacements m	$8.4\cdot 10^{-2}$	$2.5\cdot 10^{-3} - 2.5\cdot 10^{-5}$	$2.5\cdot 10^{-8}$

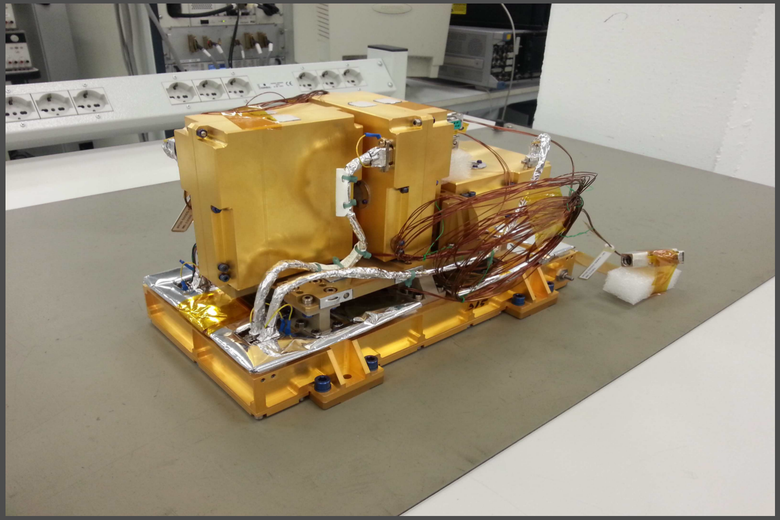
The acceleration values between the indicate points are linearly connected , while the displacements values can be found using the relation: $x = a/(2 * pi * f)^2$

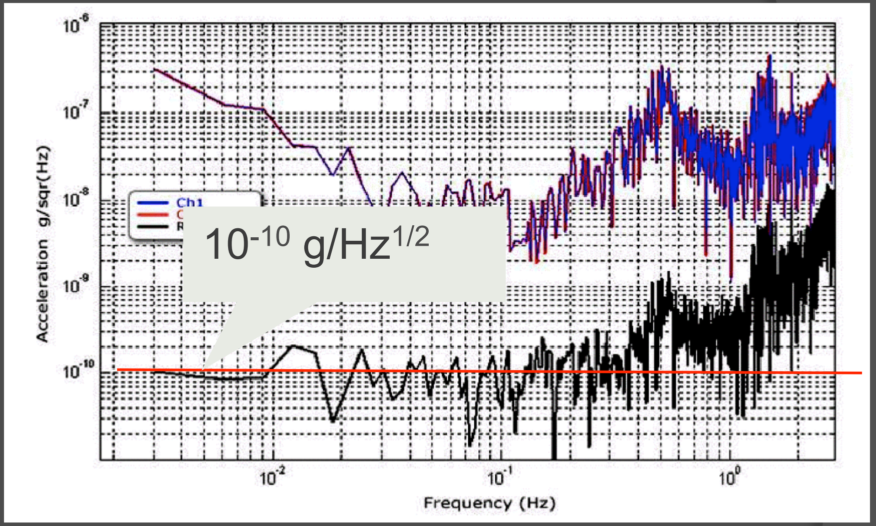


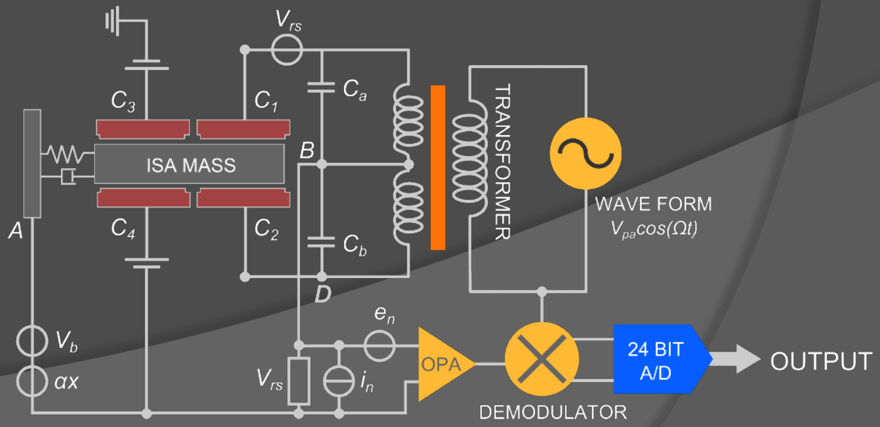
ASTRIUM ASSESSMENT
Noise presents on the MPO BepiColombo due to the motions of the solar array.
Analogue noise are due to the HGA and Reaction Wheels



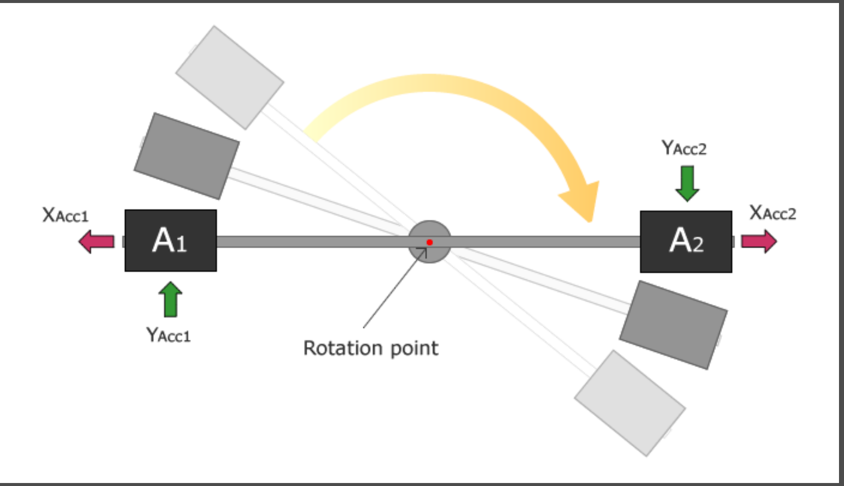
ISA ACCELEROMETER

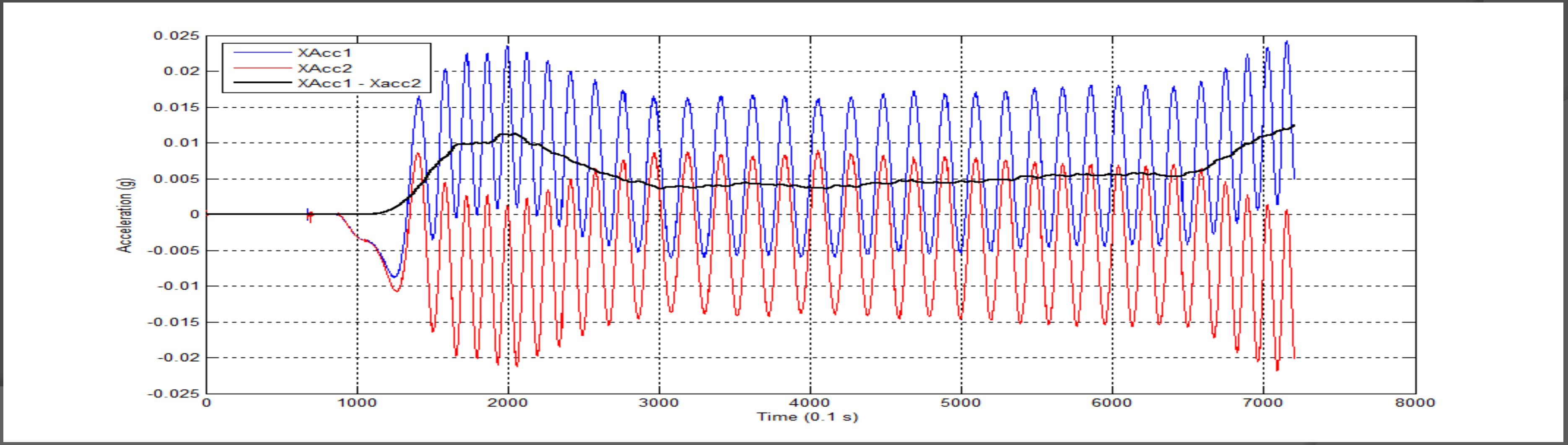




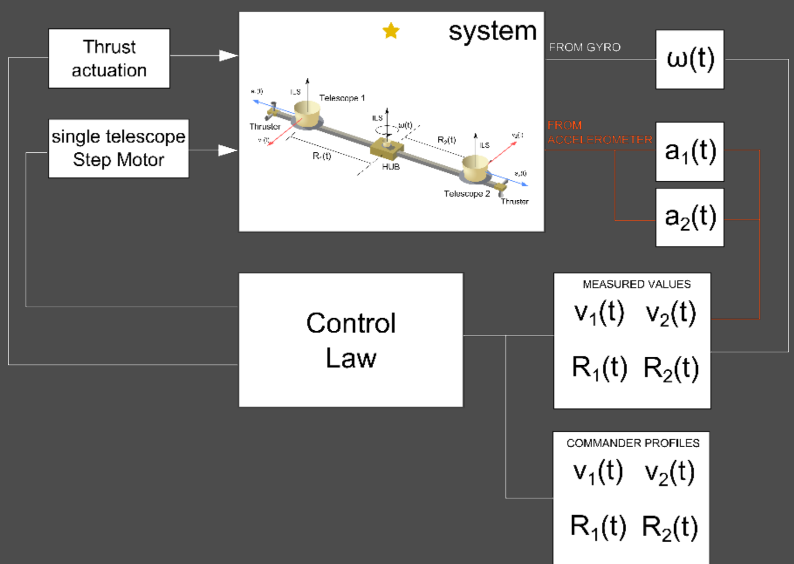


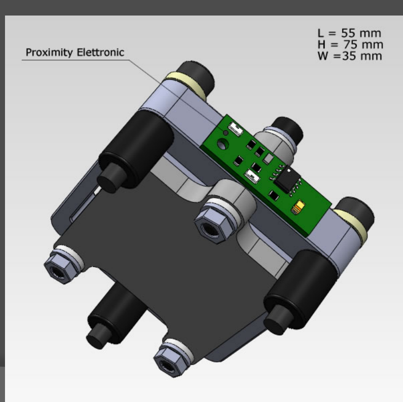
LABORATORY ACTIVITIES: TELESCOPE CONTROL- LOOP

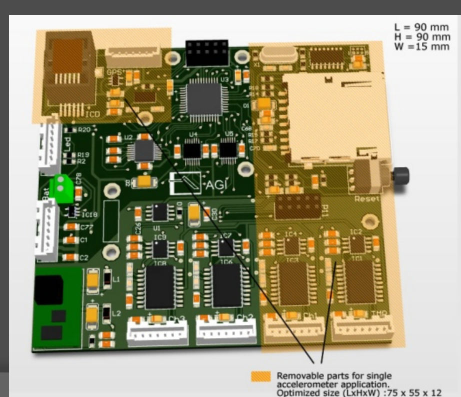




LABORATORY ACTIVITIES: NANO-SATELLITE







Sensitivity	1e-7 - 1e-8 g/sqrt(Hz)
Acquisition frequencies (Hz)	0.1,0.2,0.5,1,5,10,20,50,100
Output	Analogic or digital
Data rate (10Hz one acc. And one T) [byte/s]	250
Internal thermometer Pt10000	Precision better than 10^{-4} °C
Interface of communication	Rete RS232 full-duplex/Rete RS485 (con adattatore)
Standard of communication	NMEA
Dimensions of a single axis mechanical element	80 x 60 x 25 (H x L x A)
Electronic dimensions for a single element [mm]	75X55X12
Voltage supply via USB or external [V]	5
Power dissipation	75 mW
Weighs [Kg]	0.200
Linearity	> 80 dB
Internal memory	SD 2Gb

Conclusions