Analysis and test of a critical mechanism for the LISA mission (ID #222)

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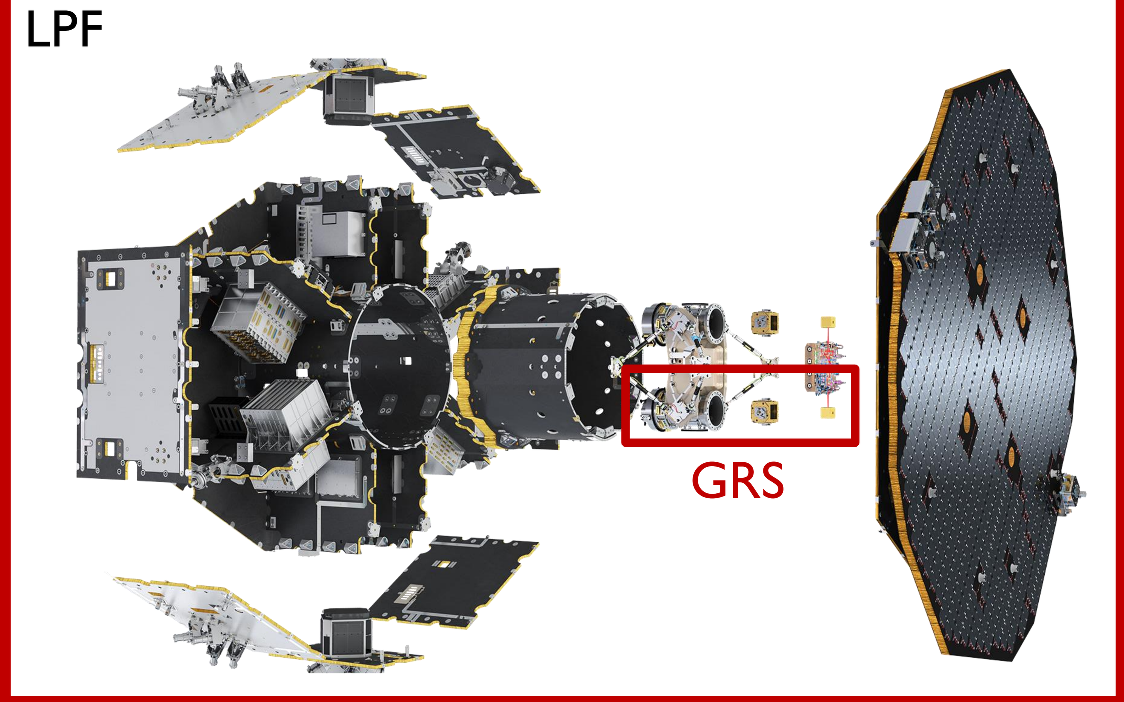
From LISA Pathfinder to LISA

LISA Pathfinder (LPF) (2015 – 2017) is an ESA mission served as technology precursor for LISA. **LISA**, Laser Interferometer Space Antenna (planned for 2035), will be the first space-based **gravitational waves** detector. 3 spacecrafts in triangular formation of side 2.5 million km will trail Earth at 50 million km in its orbit around the Sun.



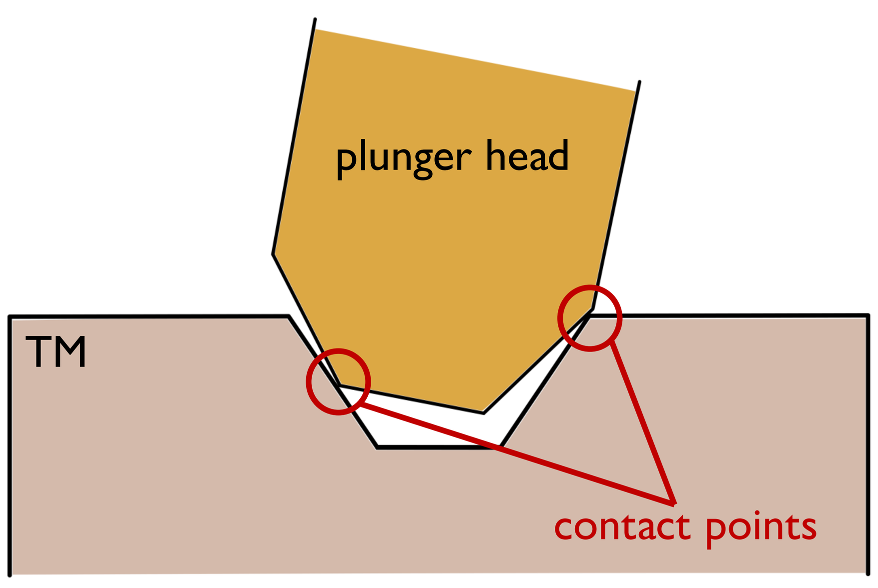
In-flight operations

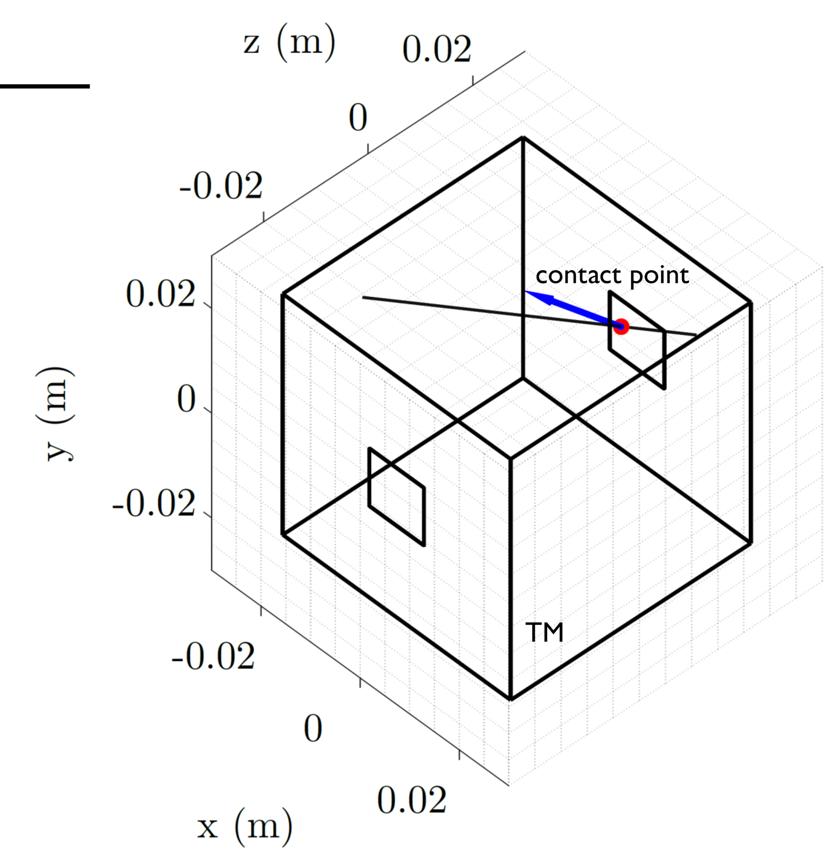
LPF included two Gravitational Reference Systems (**GRS**) each one with the Test Mass (**TM**), i.e. the interferometer sensing body. To start the science phase the TM was released into a **geodesic** by the Grabbing, Positioning and Release Mechanism (**GPRM**).

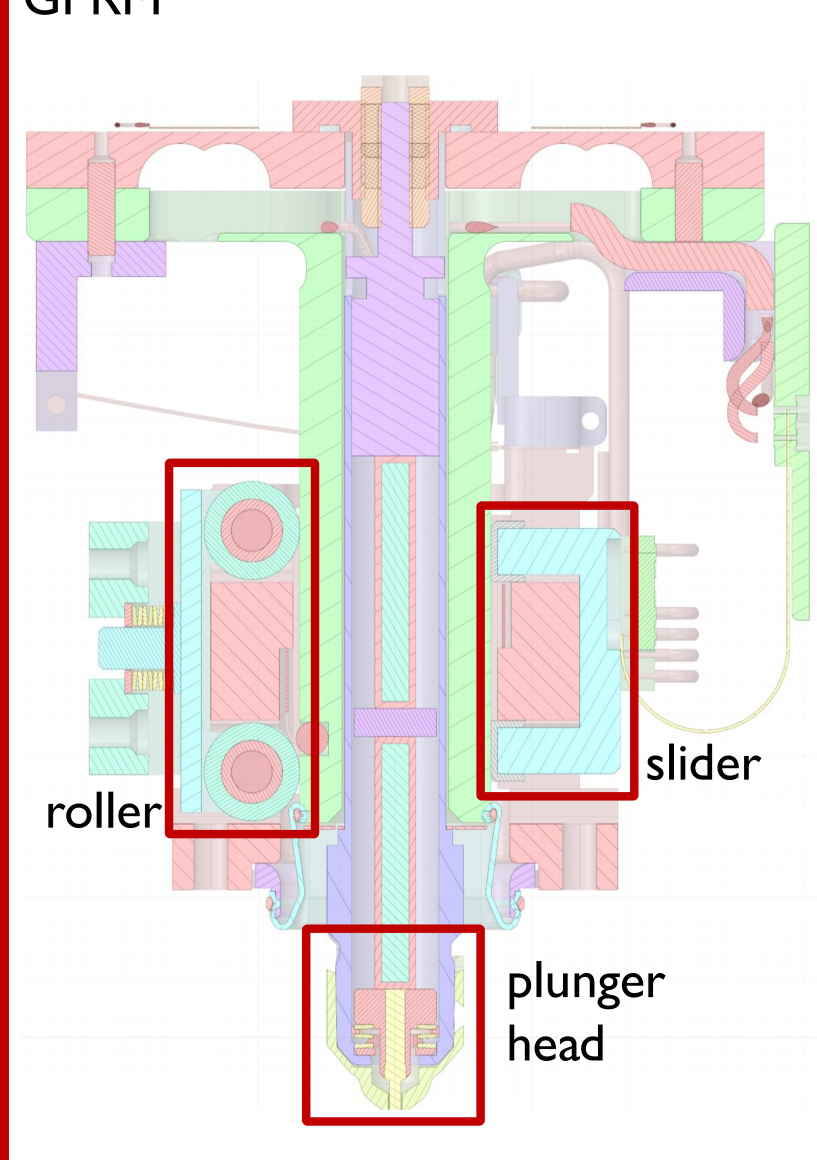
LPF anomalies

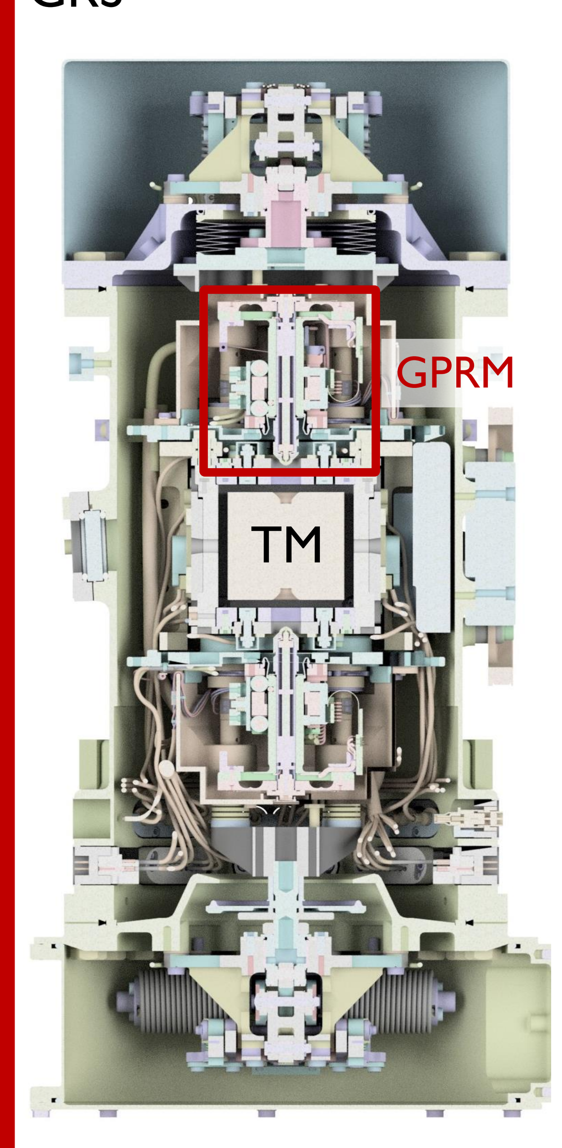
component	required	expected	TM_1	TM_2	Unit
v_x	5	≈ 0	−3	+12	$\frac{\mu m}{s}$
v_y	5	≈ 0	−20	−27	
v_z	5	< 5	−57	−16	
ω_x	100	≈ 0	+681	+1035	$\frac{\mu rad}{s}$
ω_y	100	≈ 0	−797	−30	
ω_z	100	≈ 0	−1085	−430	

The TMs showed non-compliant velocity at the release caused by **impacts** between the TM and the GRPM end-effectors.

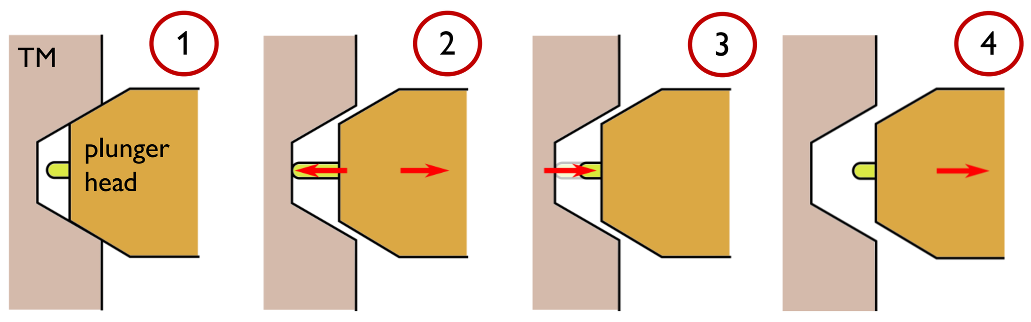








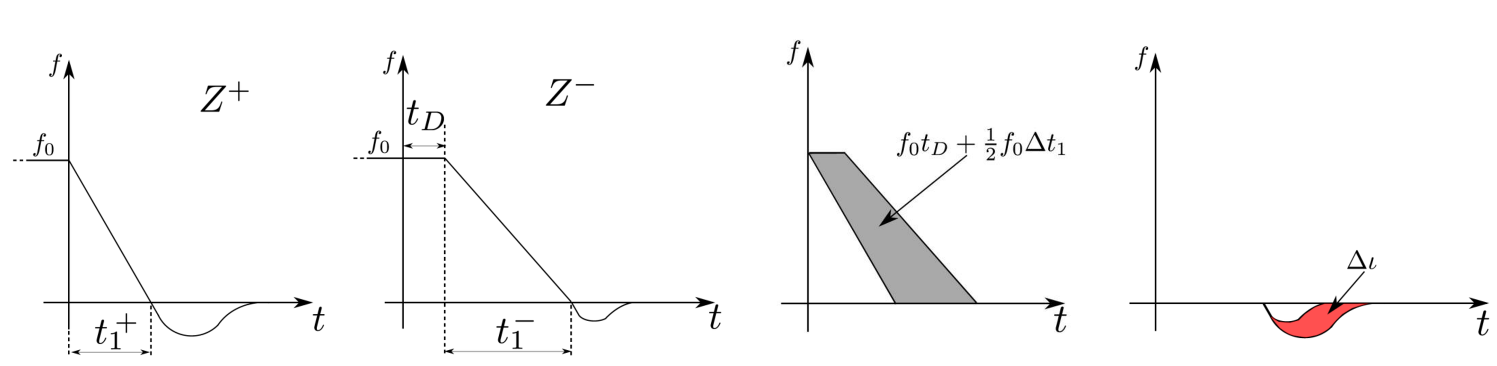
Removing the anomaly



Nominal TM release:
1. Grabbing
2. Handover
3. Tip retraction
4. Plunger retraction

The TM linear momentum at the release can be written as:

$$I_{z,res} = f_0 t_D + \frac{1}{2} f_0 \Delta t_1 + \Delta\iota \approx f_0 t_D + \Delta\iota$$



contribution	t_D	$\Delta\iota$	$\pm\iota$	Δt_1
$\mu \pm \sigma \left(\frac{\mu m}{s}\right)$	1.7 ± 0.8	0.00 ± 0.12	0.58 ± 0.08	0.00 ± 0.04

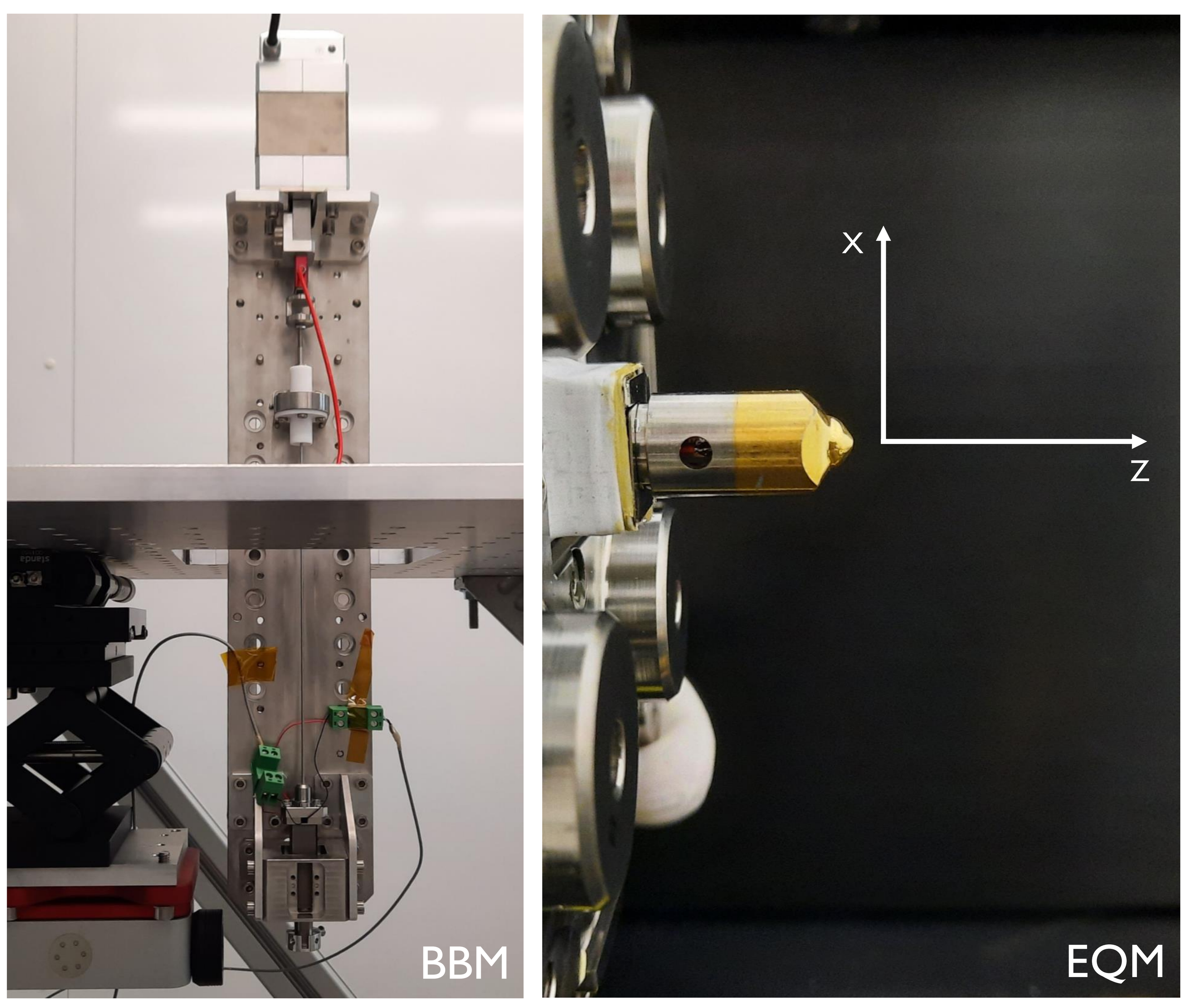
Removing impacts from the in-flight performance, the underlying dynamics is compatible with the on-ground testing and compliant with the design requirements.

Under this assumption, the probability that $I_{z,res} \le I_{z,req} = 10 \frac{kg\,\mu m}{s}$ is studied:

f_0 (mN)	$P(f_0 t_D + \Delta\iota \le I_{z,req})$	$P(f_0 t_D - \iota \le I_{z,req})$	$P(f_0 t_D + \iota \le I_{z,req})$
100	100.00 %	100.00 %	100.00 %
300 (nominal)	99.99 %	100.00 %	99.98 %
500	97.46 %	100.00 %	88.53 %

The **GPRM re-design** should be aimed at avoiding any undesired interaction between the plungers and the TM at release.

GPRM delta-development



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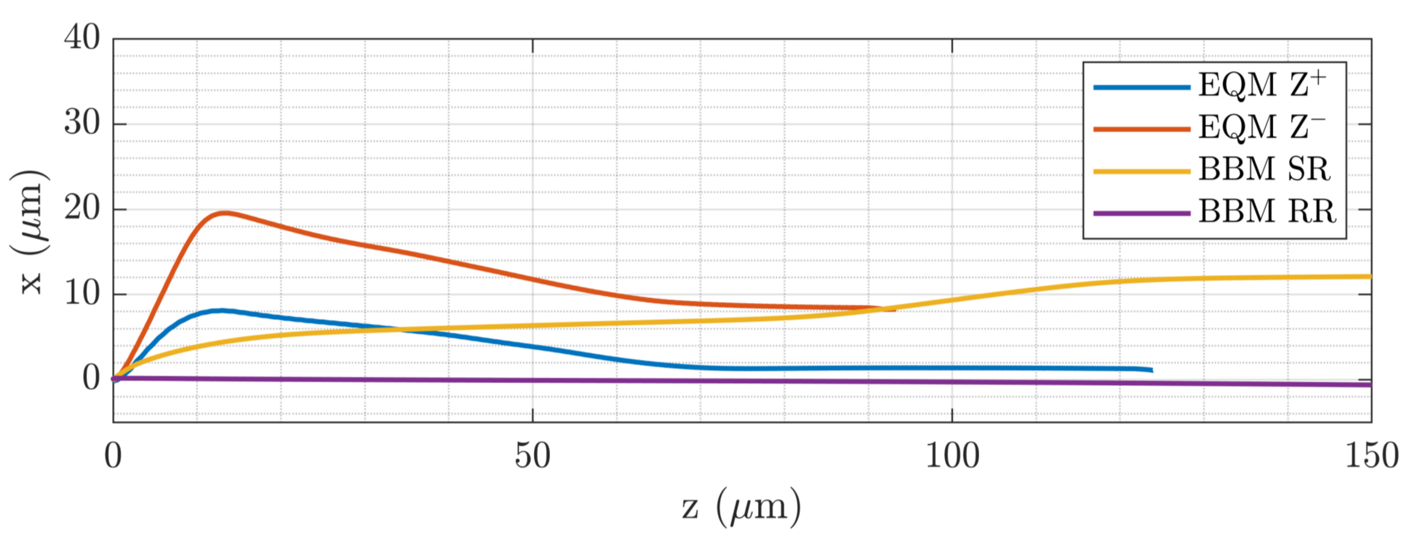

During the motion along z, the plunger head is subjected to an **hysteretic behaviour** in the xz plane due to the **side guiding**. The reduction of this unwanted behaviour is part of the GPRM **delta-development** for LISA.

References

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