Design and testing of an improved LISA grabbing, positioning and release mechanism

GRAvitational-waves Science&technology Symposium (GRASS 2024)

October 2nd, 2024

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GRS Mechanisms

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- allows survival to launch loads;
- enables science phase

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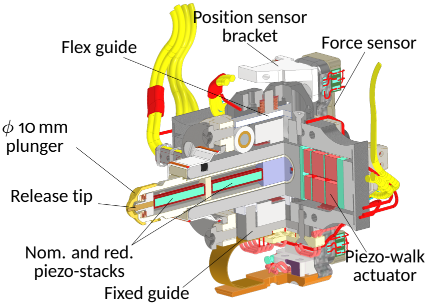
Lack of reliability in LPF!

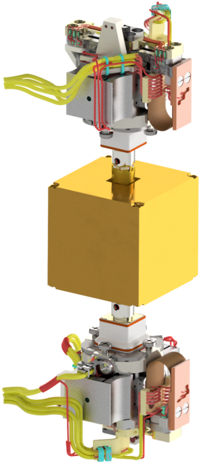
to be solved with delta-design
for LISA without violating
the LPF GRS science **heritage**

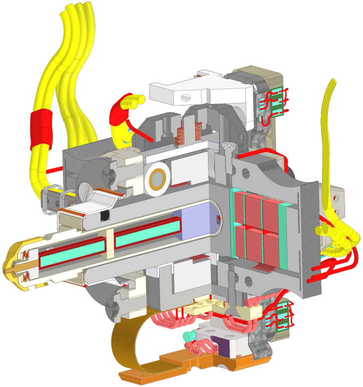
GPRM

Grabbing, **P**ositioning and **R**elease **M**echanism.

Mechanism responsible for the TM positioning and release.



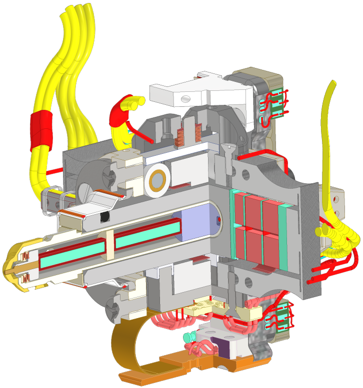




Main goal

release the test-mass with the lowest residual velocity.

The **release procedure** is made of 4 main steps



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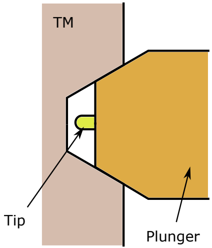
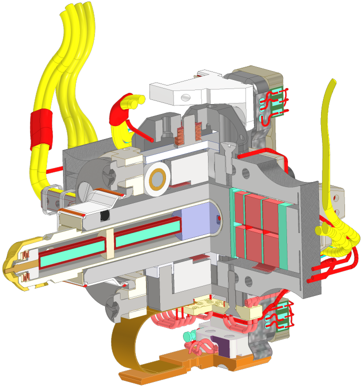
Grabbing





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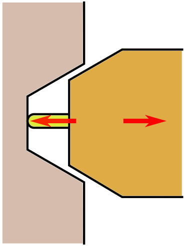

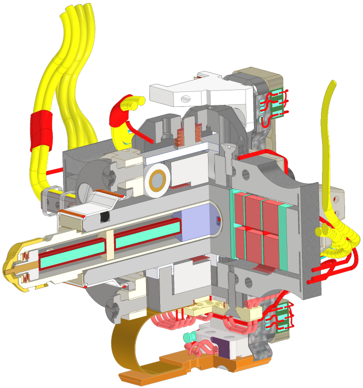

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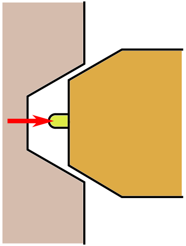
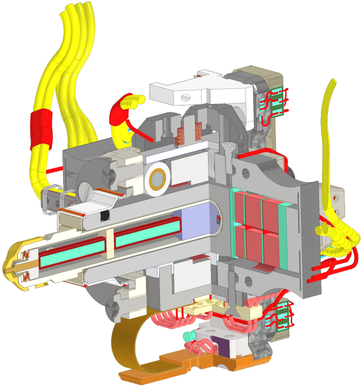
Tip retraction





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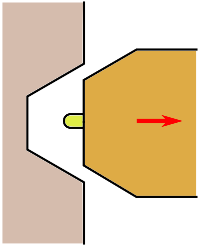
Plunger retraction



Release performance

In LPF, TM was not released within the requirements.

GPRM identified as critical in LPF.

DOF	Unit	Residual velocity LPF Req.	TM1	TM2
t_x	$\mu m\, s^{-1}$	5	-3	+12
t_y		5	-20	-27
t_z		5	-57	-16
r_x	$\mu rad\, s^{-1}$	100	+681	+1035
r_y		100	-797	-30
r_z		100	-1085	-430

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Causes	**Effects**
Adhesion Tip retraction time lag TM-Plunger electrostatic attraction Plunger anomalous trajectory Mechanism vibrations Integration and manufacturing tolerances	

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TM-Plunger electrostatic attraction	X
Plunger anomalous trajectory	
Mechanism vibrations	
Integration and manufacturing tolerances	

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Causes	**Effects**	
	Spurious forces on TM	Gap reduction
Adhesion	X	
Tip retraction time lag	X	
TM-Plunger electrostatic attraction	X	
Plunger anomalous trajectory		X
Mechanism vibrations		X
Integration and manufacturing tolerances		X

DOF	Unit	Residual velocity LPF Req.	TM1	TM2
t_x	µm s^{-1}	5	-3	+12
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Causes	**Effects** Spurious forces on TM	Gap reduction	Plunger-TM re-contact
Adhesion	X		
Tip retraction time lag	X		
TM-Plunger electrostatic attraction	X		
Plunger anomalous trajectory		X	X
Mechanism vibrations		X	X
Integration and manufacturing tolerances		X	

GAP FACTOR (G)

Index defining the re-contact probability.

Indipendent for the two planes X-Z and Y-Z

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Relative TM-plunger configuration is converted into relative plunger-indent misalignment.

Maximum allowable misalignment is defined by the nominal TM-plunger gap at the handover.

$$G_{X-Z} = \frac{\delta x_{\mathrm{eq}}}{\delta x_{\mathrm{max}}} + \frac{\delta z_{\mathrm{eq}}}{\delta z_{\mathrm{max}}} \leq 1$$

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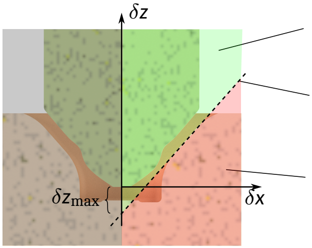

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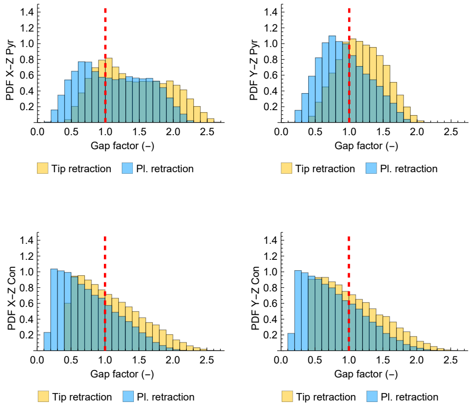
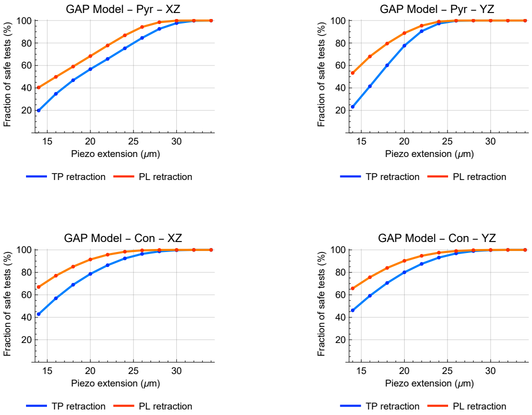
LPF case:



Tip stroke

Performance of the stack unit

The stroke of the tip is directly connected to the TM-plunger gap at the handover: increasing the tip stroke, the probability of re-contact decreases.



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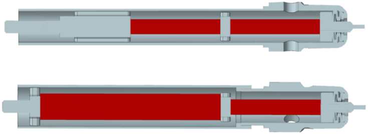
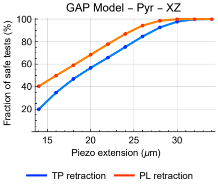
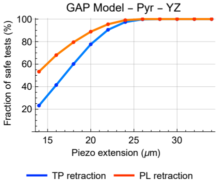
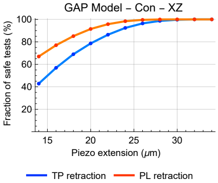
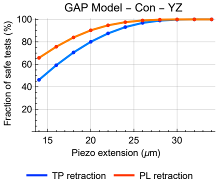
The piezo-stack actuators commands the motion of the tip: commercial solution are compared with gap model outcome to obtain close to 100% of safe tests.











Side guiding system

Reduction of the anomalous motion of the GPRM

Anomalous motion of the GPRM:
when the plunger inverts the motion (in Z), the plunger head moves laterally (along X).

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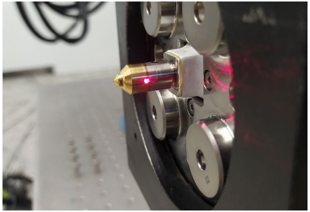

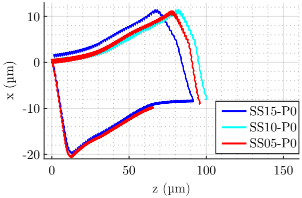

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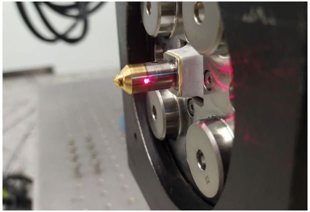

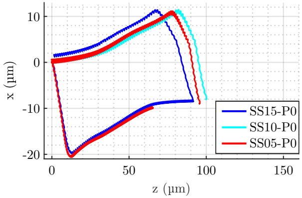

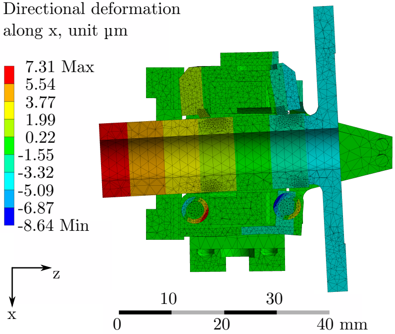

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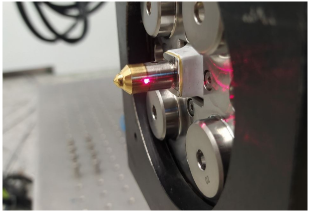

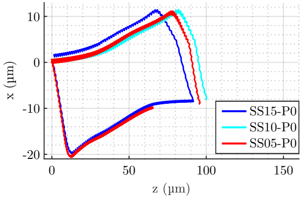

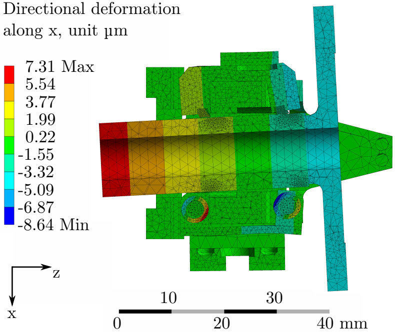

The cause of this was identified on:

- the asymmetry of the guiding system friction
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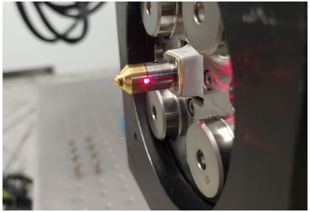

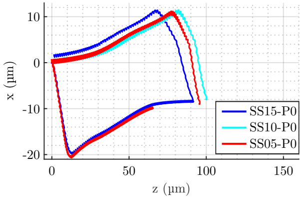

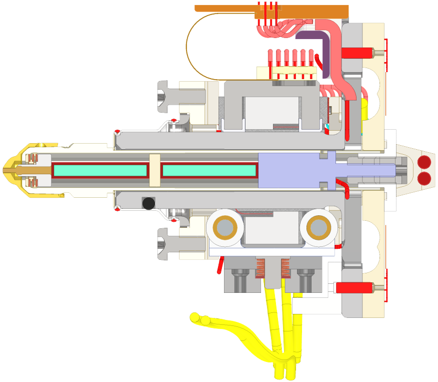

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Testing GPRM improvements

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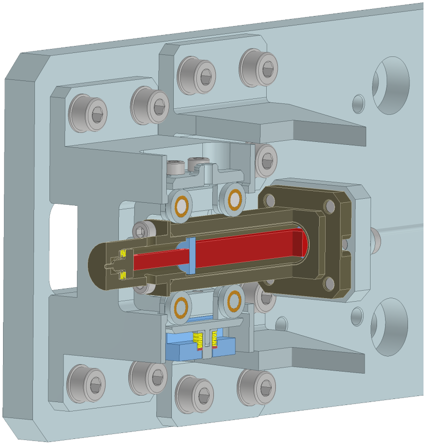
- off-the-shelf piezo-walk actuator
- commercial control electronics



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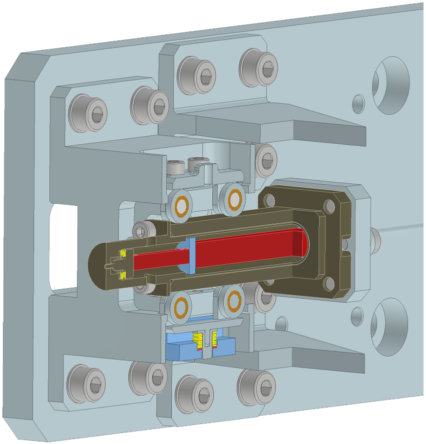
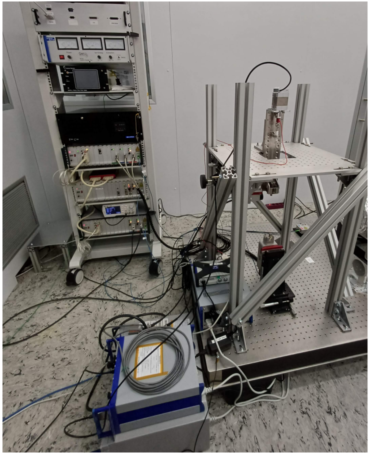
The LPF guiding system is also tested as a reference.



Breadboard model
Testing GPRM improvements

BBM is tested in the UniTN laboratory.

Tests are performed on an anti-vibration platform inside a cleanroom.



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The mechanism trajectory is measured by:

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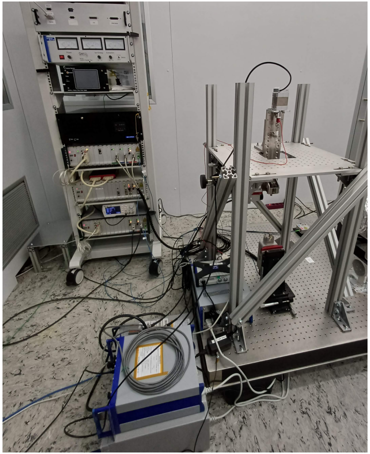
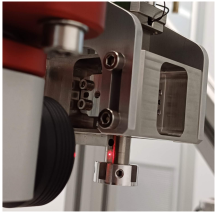
  - lateral (X) displacement





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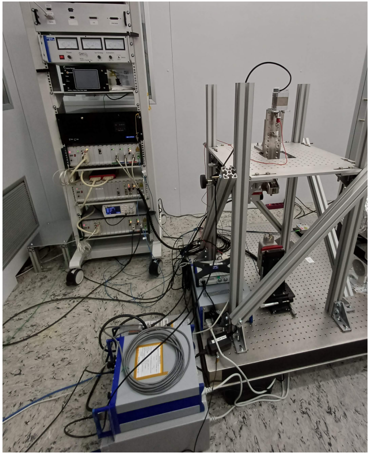
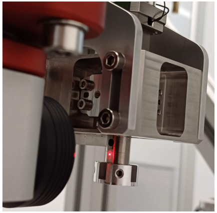
- 3 beams laser interferometer
  - axial (Z) displacement
  - X and Y rotations





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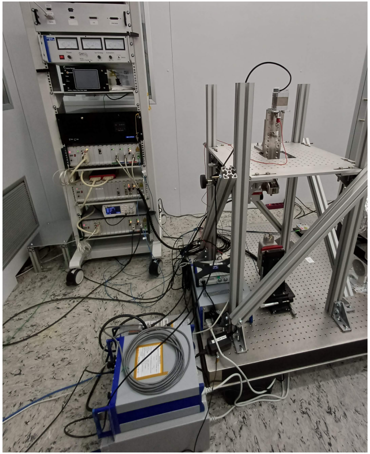
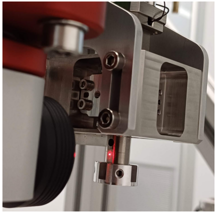
The mechanism trajectory is measured by:

- 1 beam laser interferometer
  - lateral (X) displacement
- 3 beams laser interferometer
  - axial (Z) displacement
  - X and Y rotations
- load cell
  - total friction force





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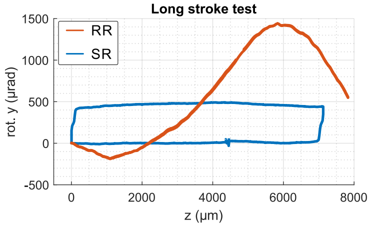

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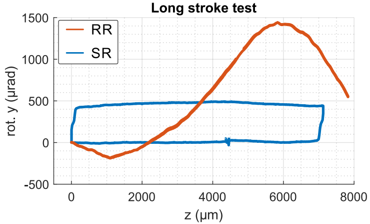
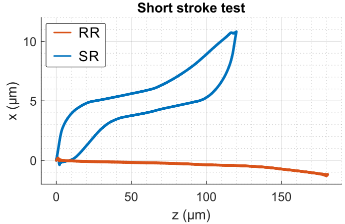
- lower lateral displacement at the inversion
  - critical in case of handover after grabbing





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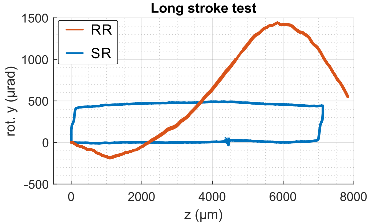
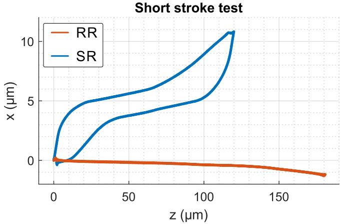
NOTE:
close to the TM, at the release, GPRM is likely to a motion-inversion configuration.

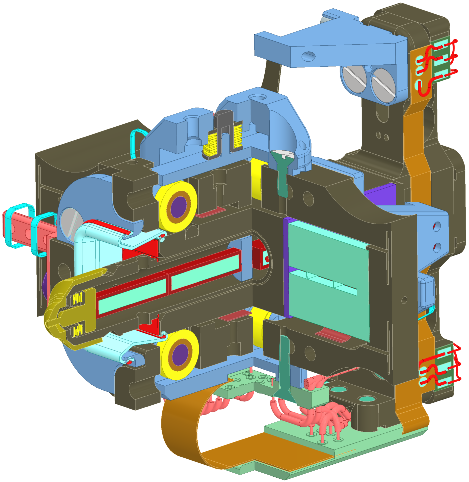




LISA Baseline

Improved GPRM for LISA

Design of GPRM under internal review to increase the mechanism performance



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- Roller-roller side guiding configuration
  - Lower lateral displacement close to the TM
- 2 equal 27 mm piezo-stacks
  - 27 µm of tip stroke
- Improved force sensor
  - Lower pre-release TM preload
- Improved tollerances verification process

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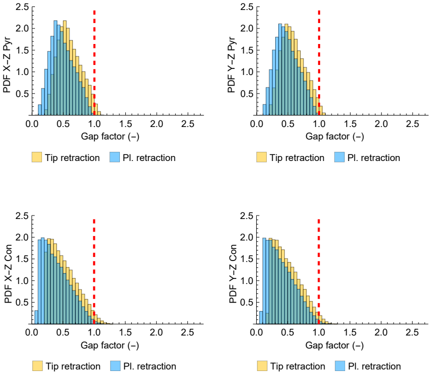
  - Lower pre-release TM preload
- Improved tollerances verification process



GRS Mechanisms

FUNCTIONALITY

Conclusion

Future of the mechanisms in a LISA-like mission

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NECESSARY & MAJOR DESIGN CONSTRAINT FOR GRS

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- cables inside vacuum;
- actuators inside vacuum;
- volume availability;
- EH actuation and sensing;
- . . .

Conclusion

Future of the mechanisms in a LISA-like mission

GRS Mechanisms

FUNCTIONALITY

GRS mechanisms shall be revised to increase future LISA-like missions performance

NECESSARY & MAJOR DESIGN CONSTRAINT FOR GRS

- cables inside vacuum;
- actuators inside vacuum;
- volume availability;
- EH actuation and sensing;
- …

Main references:

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Thank you for your attention!