# A New Concept for LISA
## Based on Torsion Flexure and DFP

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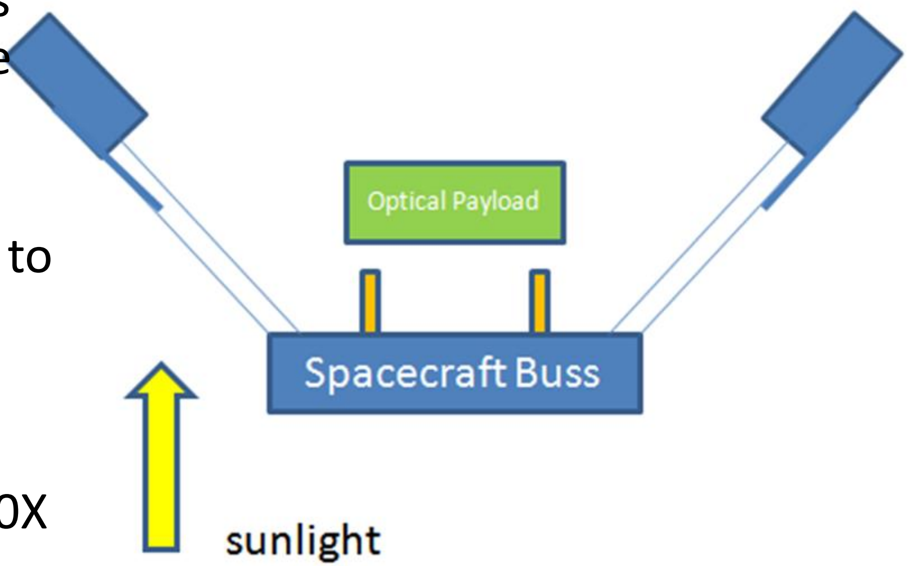
# Overview of Concept

- We looked at the two major technological hurdles to LISA Pathfinder and propose an alternative architecture to avoid the development of new potentially expensive technologies.
  - Very precise, ultralow thrust, long lifetime thrusters
  - Holding the proofmass during launch and in operation.
- LISA is a very technologically challenging mission, with some technologies that can only be demonstrated in a space experiment. Technical problems encountered in developing these technologies can drive cost up, if only because the reserves have to be increased.
  - Sometimes it's possible to change the experiment architecture to avoid the need for extremely challenging technologies that can only be demonstrated in space.
- Disturbance free payload architecture can be thought of as a 2 stage drag free platform, removing the need for Feep type thrusters
- Torsion flexure suspension for the proof mass avoids a huge raft of systematic technical problems and systematic errors in LISA.

# Disturbance Free Payload
## (2 stage drag free S/C)

- The optical payload (with proof mass) is shielded from the Sun (photon pressure and solar wind) By the S/C buss.
- Consequences
  - S/C fly to ~1um vs 1nm (self gravity to $3x10^{-15}$ m/$s^2$ )
  - Optical payload passively cooled to ~40K
    - Radiometer effect reduced 1000X
- Control of optical payload done with non-contact actuators. Sensors for 6DOF control in optical payload.
  - S/C flys wrt optical payload using cold gas thrusters.
- Power and data between S/C and Optical payload via optical means.

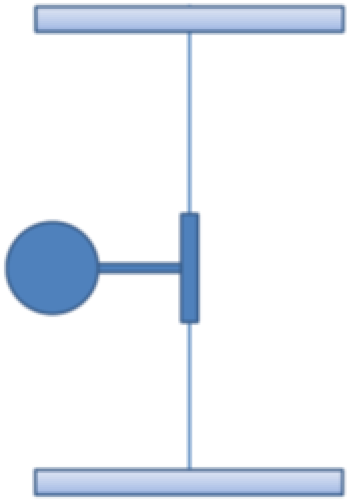


# Proof Mass Assembly

- Current LISA design of the Proof mass assembly uses a free floating conducting mass, in close proximity to electrodes that are used to both measure the position of the PM and control its position (6 dof).
  - The electro static forces are very weak, and if the PM ever touches the walls, electro-static control ceases.
  - Hence when the PM is released after launch, the velocity has to very low. This has proved to be challenging, and hence potentially quite expensive.
  - The free floating mass will also be charged by cosmic rays, and the close proximity to the walls makes it sensitive to patch effects.
- All of these issues are removed by using a torsion flexure suspension.

# Torsion Flexure Suspension

- Ground based torsion pendula provide $10^{-3}$hz resonance freq, while supporting Kg masses in 1G.
- PM release mechanism can be **10,000** times less precise.
- Suspension has just **1 DOF**. (vs 6) simpler control
- Grounded PM has much stronger electrostatic control, plants much further away, no patch effects. (eddy current damping also possible with electromagnet)
- Grounded PM doesn't build up charge from Cosmic rays.
- One drawback is thermal noise of the fiber. Mitigated with high Q fiber and 40K passive cooling.



Oscillation of the torsion pendulum after "release" can be damped with an electromagnet (eddy current damping)

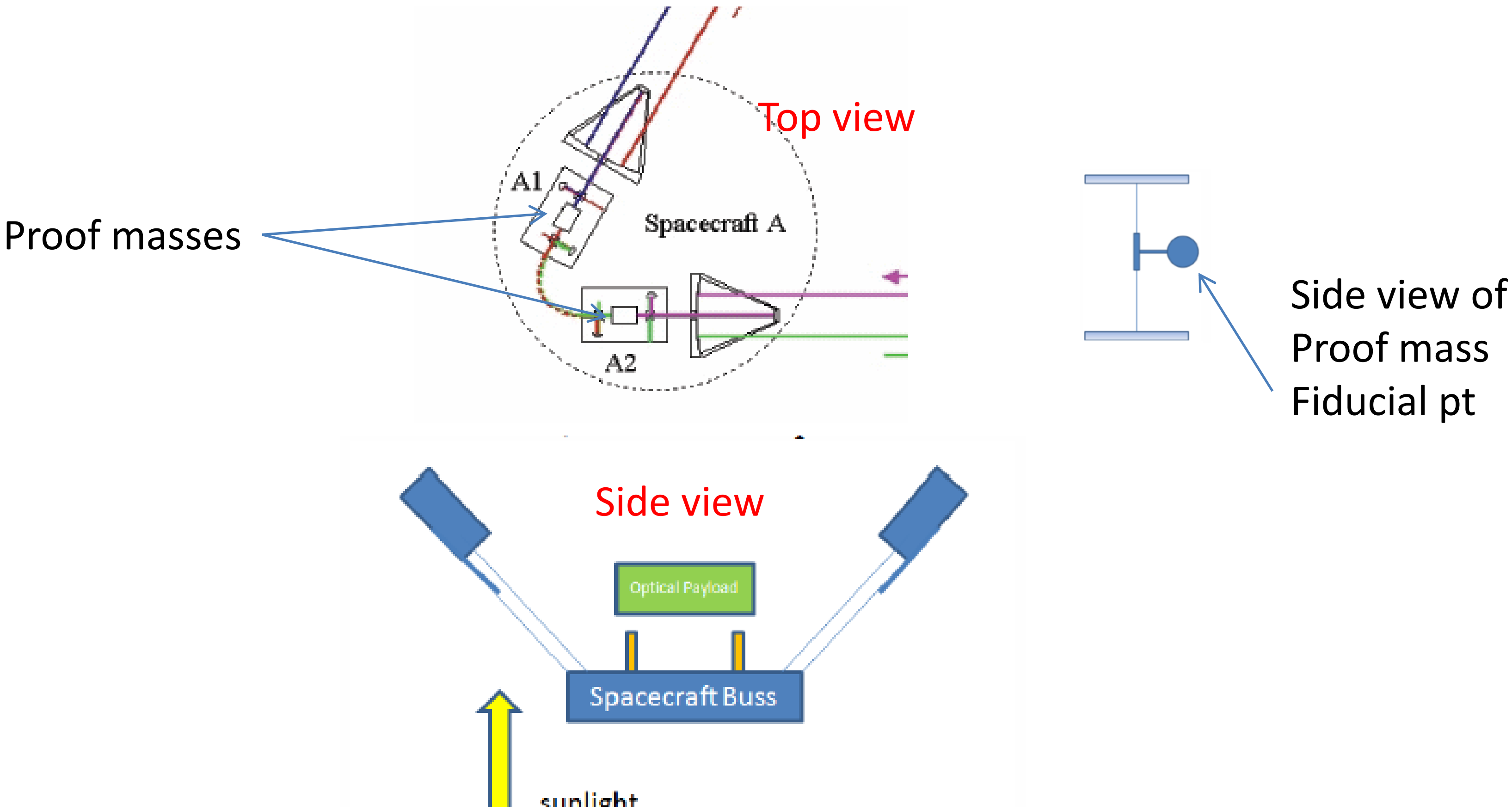
Fibers tensioned after launch

# Reply to Question 1

- 1) Compared to the baseline LISA concept, what requirements have been relaxed and how do they affect the cost? It appears that the primary advantage is a reduction in dynamic range which is not a driving requirement.
- The primary cost related advantages are:
  - 1 elimination of FEEPS, or other high precision low thrust thrusters, with long lifetime requirement. (Fly to 1um rather than 1nm) (self gravity)
  - Reduction of thermal control from 1 micro-K to 1 milli-K in proof mass cavity, due to passive cooling in shadow of DFP S/C.
  - 6 DOF control to 1 DOF control of the proofmass
  - Proof mass caging mechanism. (Inability to meet performance has driven Lisa Pathfinder cost up.)
  - Relaxing these requirements will have a cascading effect on other requirements.

# Question 2

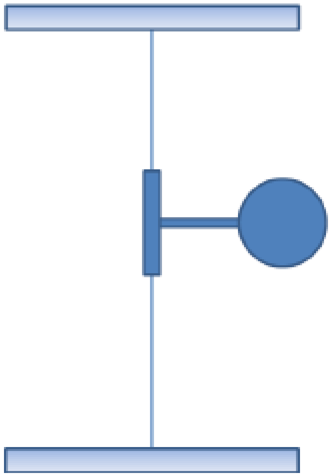
- Can you sketch a LISA-like concept using the disturbance free platform? Where is the fiducial point? The figures appear to be inconsistent.



# Question 3

- Explain the practical implementation of your torsion pendulum and the dominant noise effects?

- Proof mass is connected to fiber as shown in drawing.
  - Motion of PM is in/out of plane of paper
- Practical issues
  - Before launch, fibers are not tensioned.
  - After launch, PM is uncaged. With permitted velocity $10^n$ larger than in LISA. N>3. (residual vel can't break fiber)
  - Fiber tensioned after PM is uncaged.  Damped and adjusted so rest position is at center.
- Major noise sources (next page)



# Major Noise Effects on Torsion PM

- Thermal Effects  Radiometer effect < LISA (30~40K)
- Cross talk of PM rotation/translation << LISA (1 DOF)
- Electrical forces (patch effects)<< LISA
  - Cosmic Ray, Charged PM, (grounded PM) < LISA
- Residual gas < LISA (30K)
- Back action from position sensing << LISA
- Self Gravity ~ LISA level, but with 1um precision S/C rather than 1nm

- Thermal noise @30~40K of fiber (not in LISA)