MICRO 372 - Advanced Mechanisms for Extreme Environments

Chapter 2a

Application fields and examples

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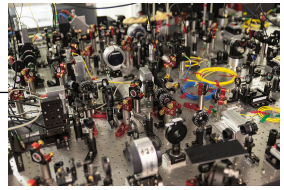
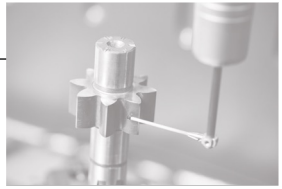
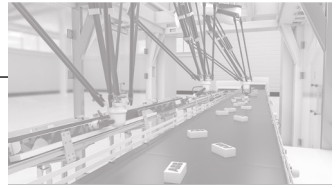
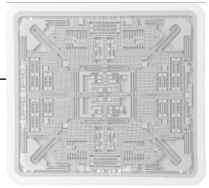
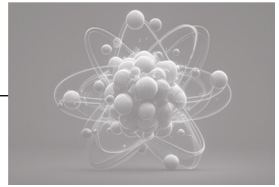
Application fields

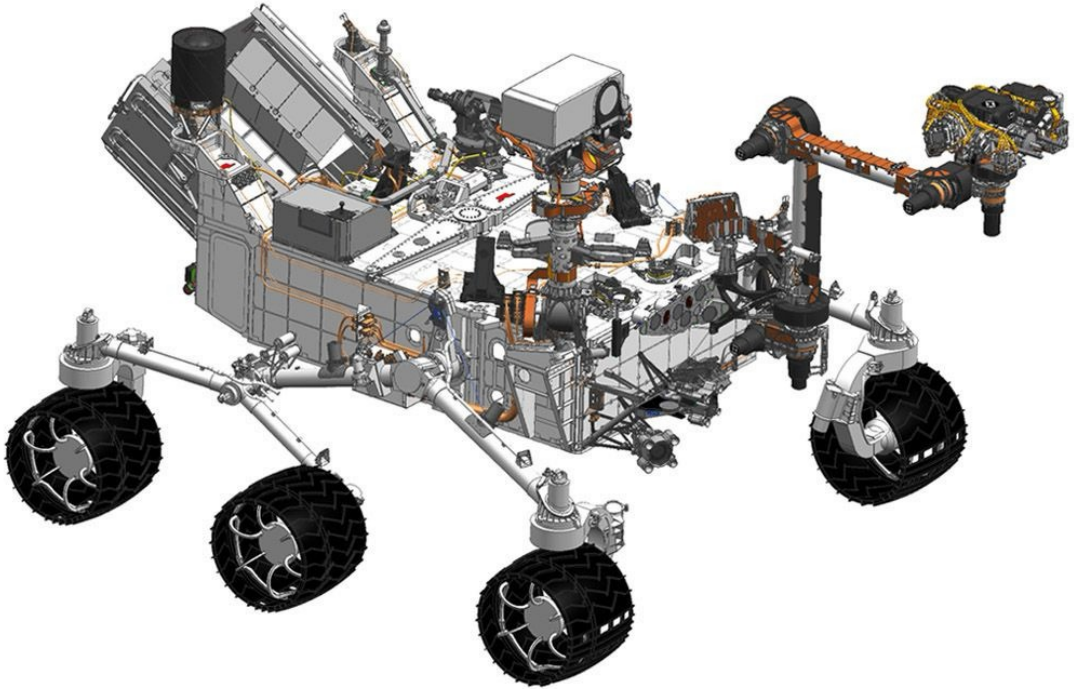
- **Space**
- **Astrophysics**
- **Optomechanics**
- Metrology
- Medical instrumentation
- Watchmaking
- Robotics
- MEMS
- Nuclear physics



Space application: Mars rover Curiosity drilling arm



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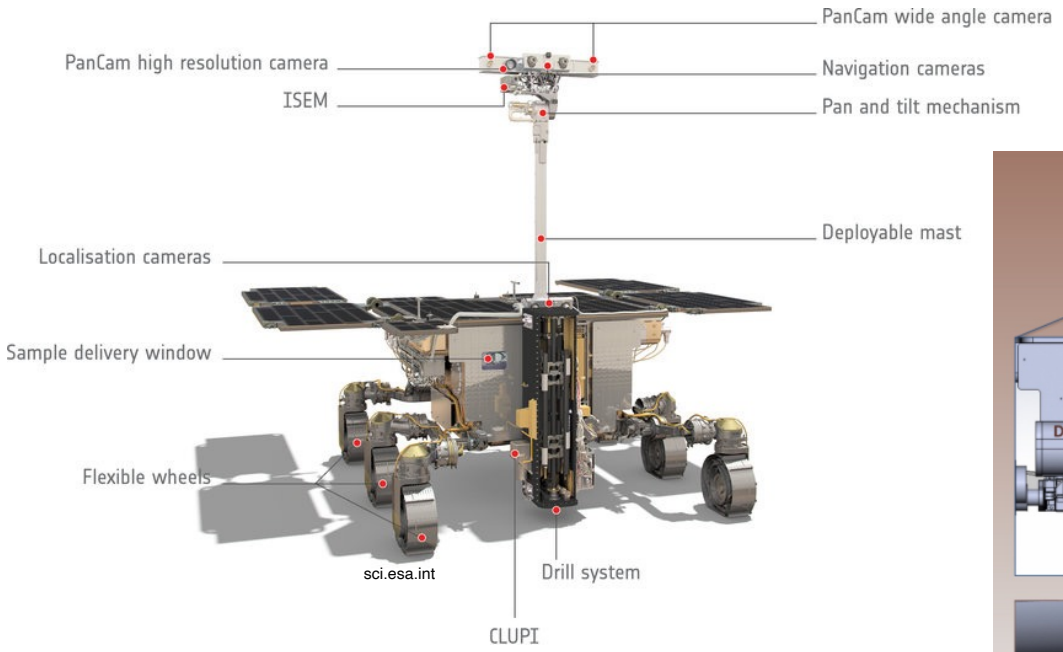
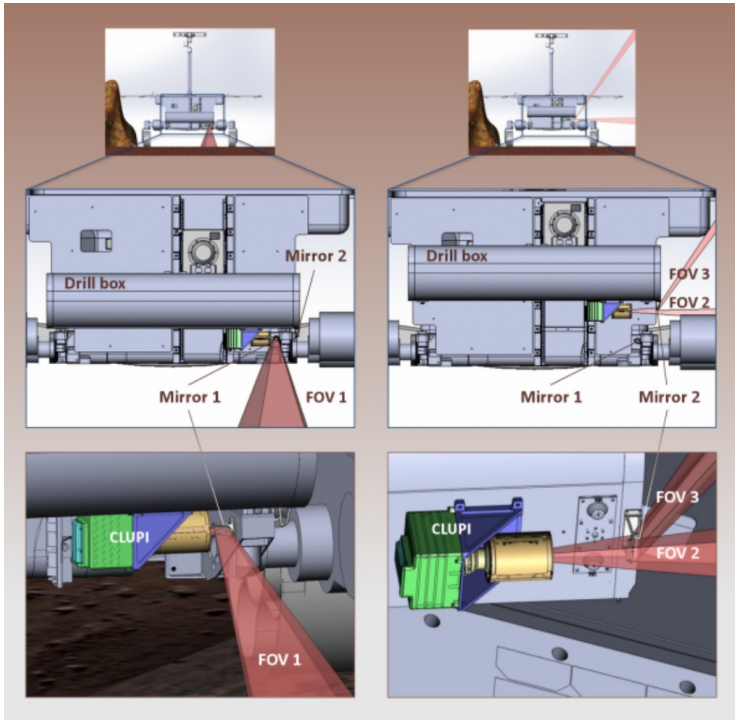
video link

Space application: ExoMars 2020 Close-up Imager (CLUPI)





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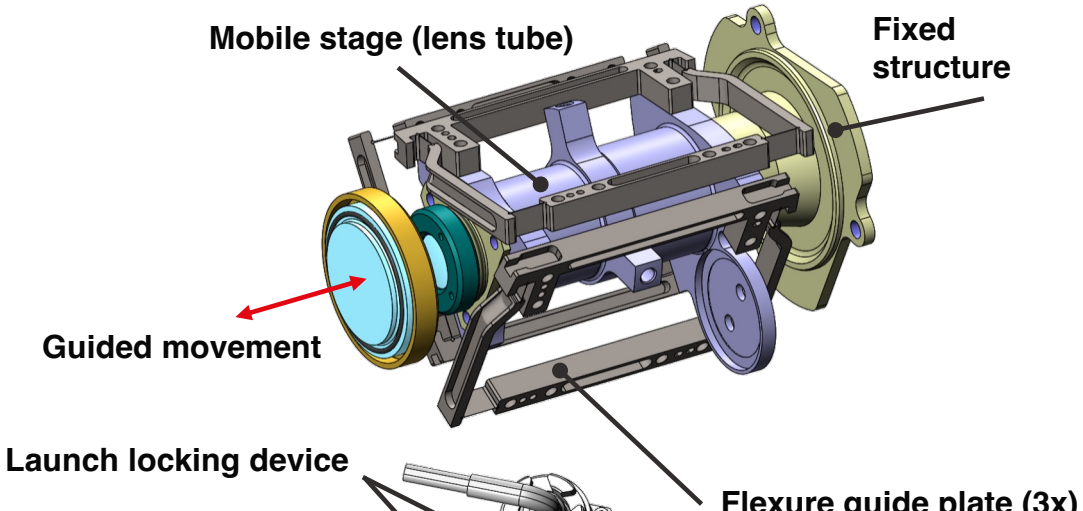
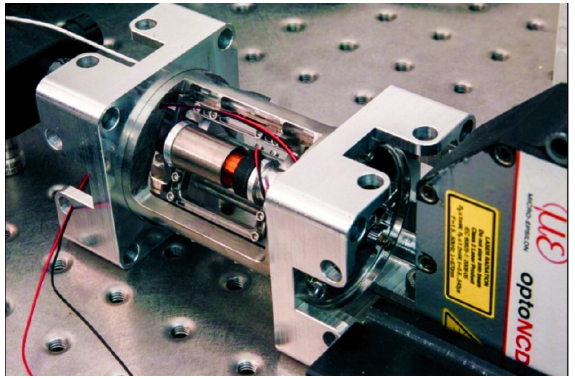
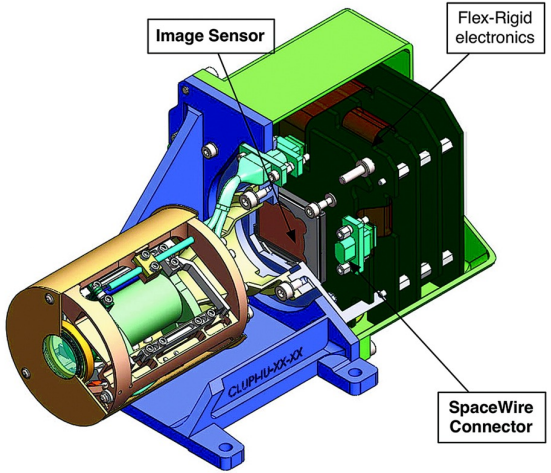
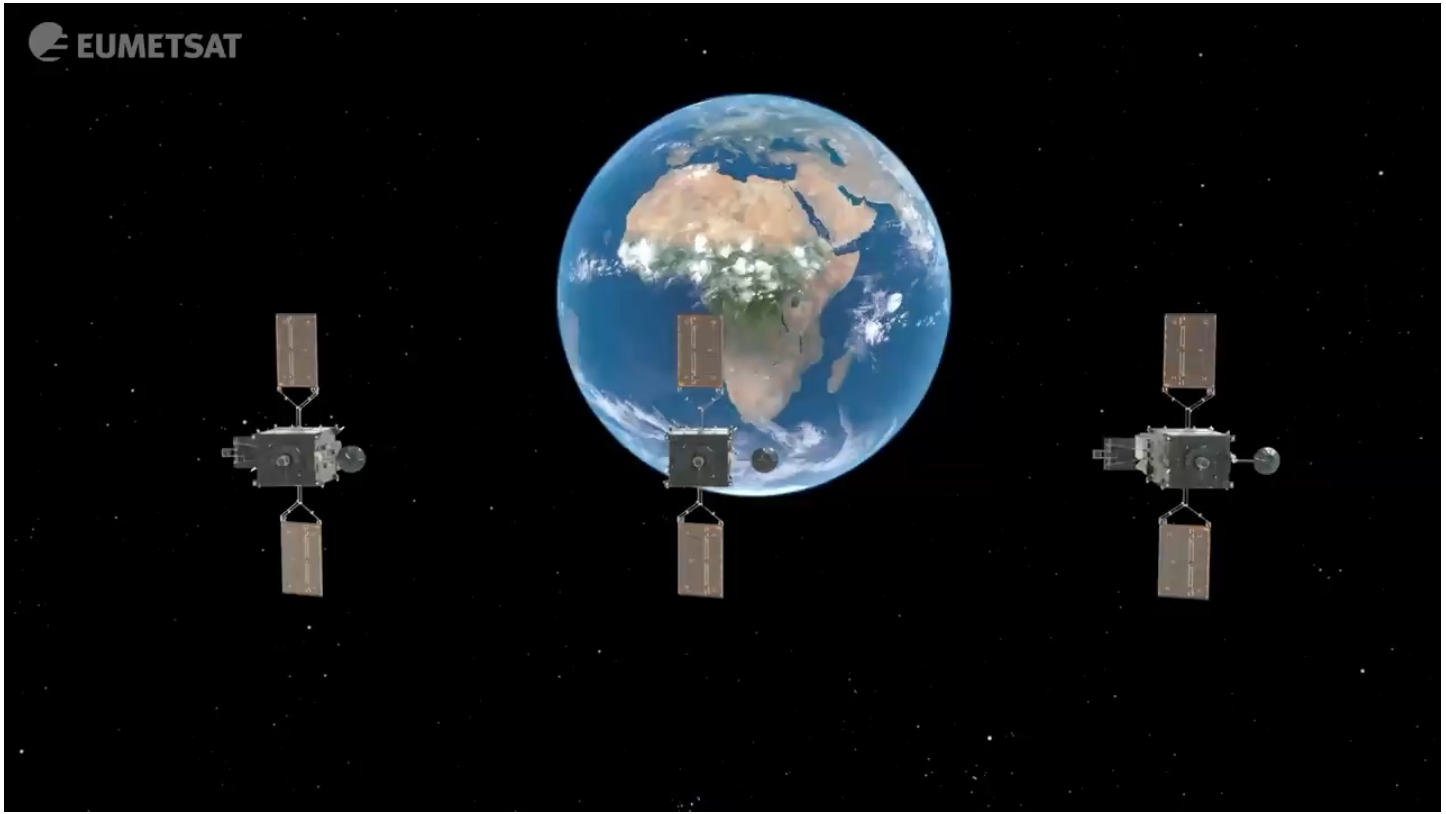






Space applications: Meteosat Third Generation (MTG) Infra-Red Sounder (IRS) Corner Cube Mechanism (CCM)



video link

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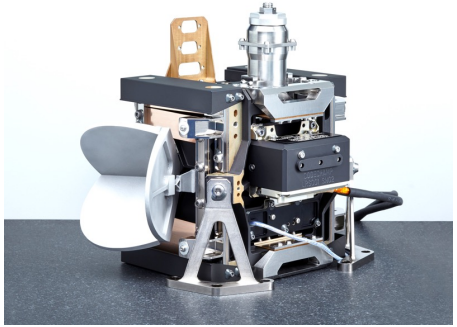
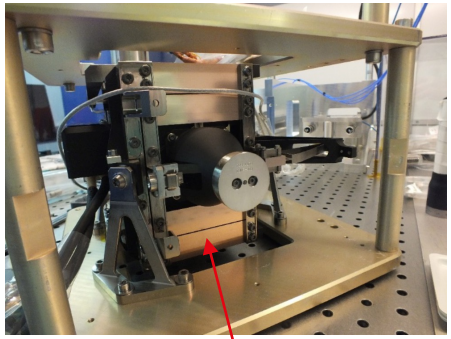
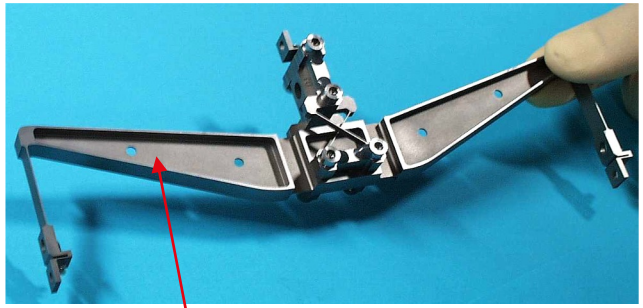


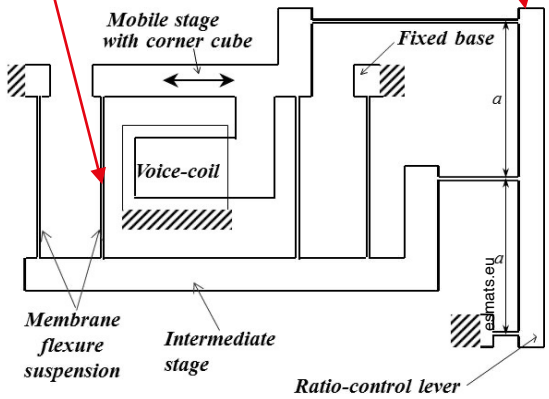


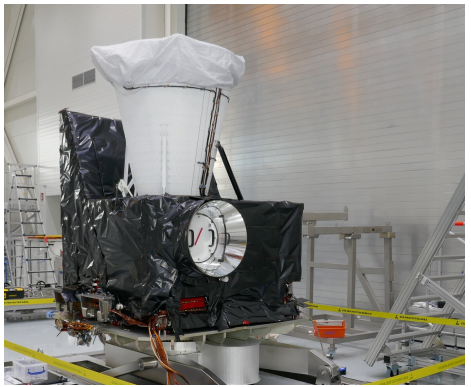


Membrane flexure suspension

Ratio-control lever

esa

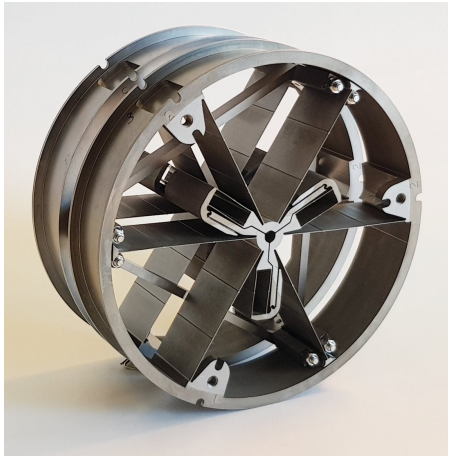


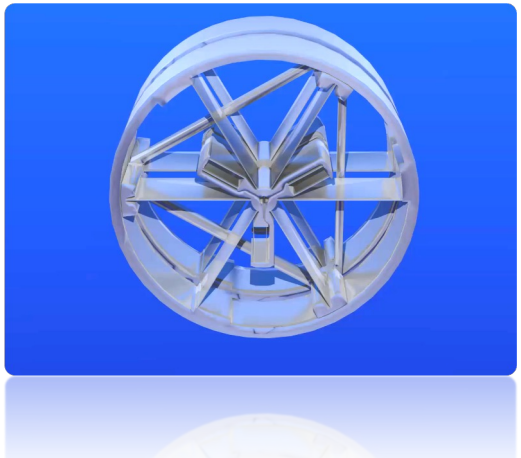


Space application: Large Angle Flexure Pivot (LAFP)

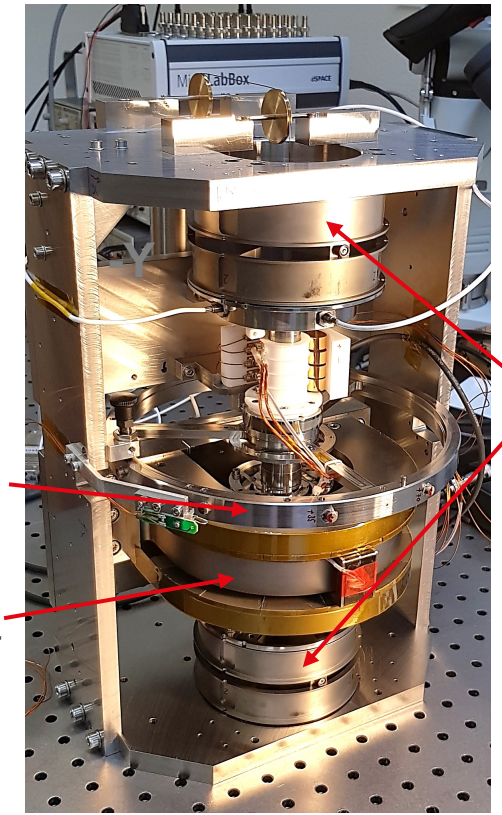
Performances:

- Stroke: ±90° (Infinite life ±70°)
- Central shift: ±35 μm at ±70°
- Angular stiffness: 0.33 Nm/rad at 90°
- Number of cycles: > 3 million
- Thermal range: -140 °C to +65 °C
- Mass: 440 g
- Dimensions: Ø 120 mm x 58 mm





Pivots mounted in test bench with payload



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Space applications: Compliant Mechanisms based on Additive Manufacturing (COMAM)

video link

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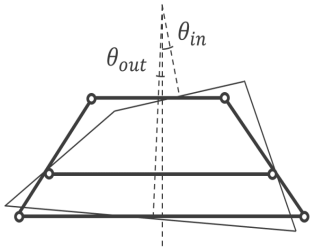
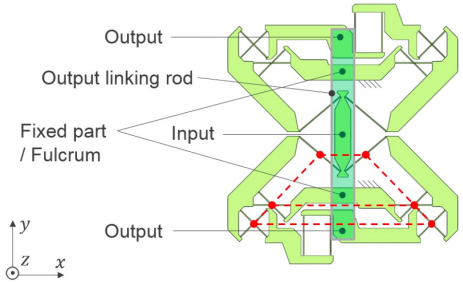
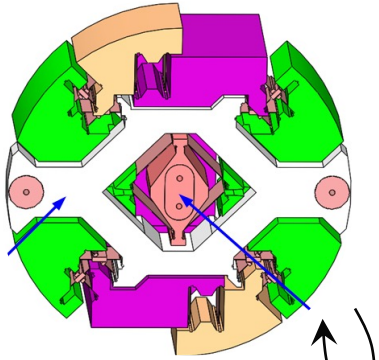


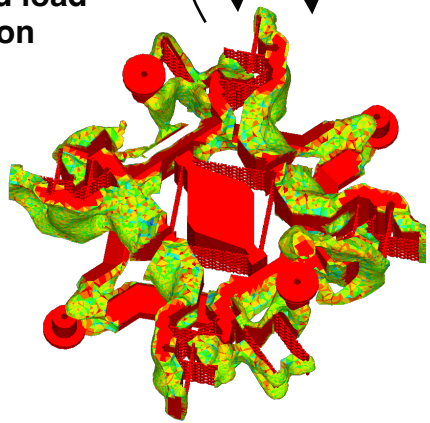
Kinematic concept



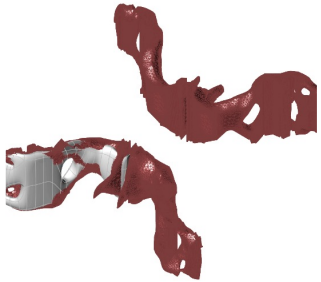
Preliminary design



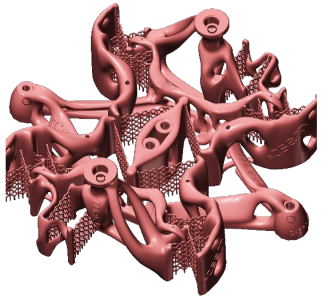
Design space and load cases definition



Optimized density design (iterative process)



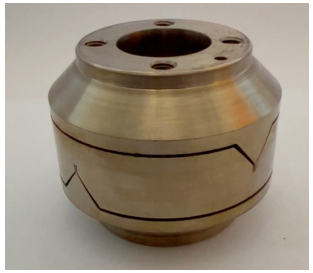
Smoothing of 3D surfaces

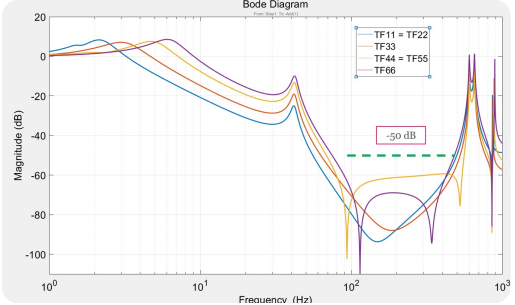


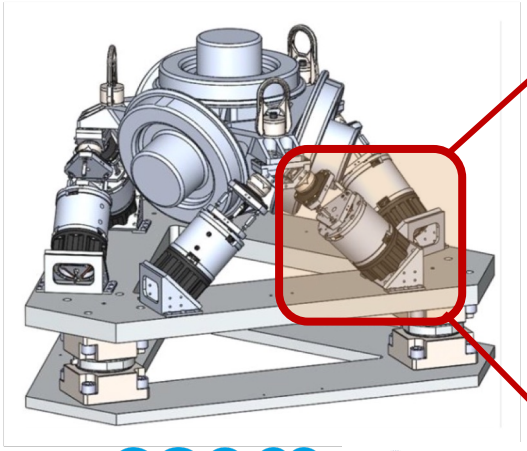
Final design with lattices and interfaces added

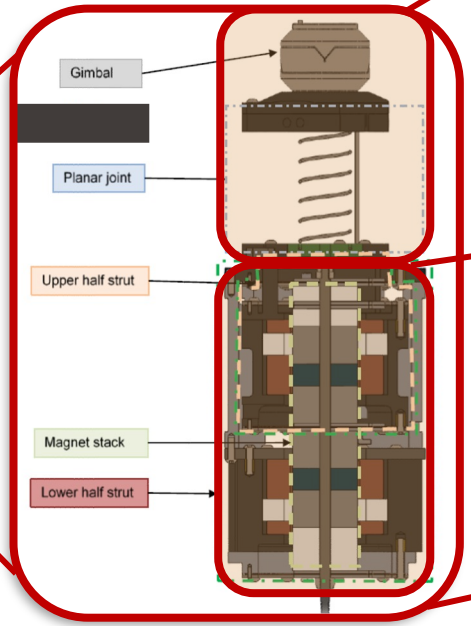
Space application: Microvibration Isolation System (MVIS)

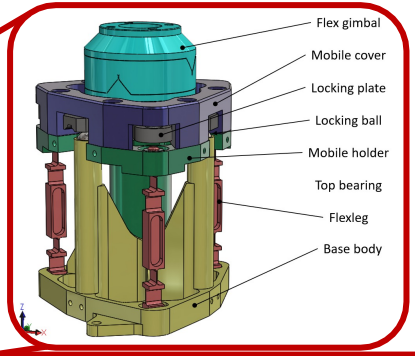
- Complete isolation system for micro-vibration mitigation
- Hexapod architecture with 6 DOFs on each strut
- Semi-passive EM damping on elongation DOF
- 25 kg payload (reaction wheels)

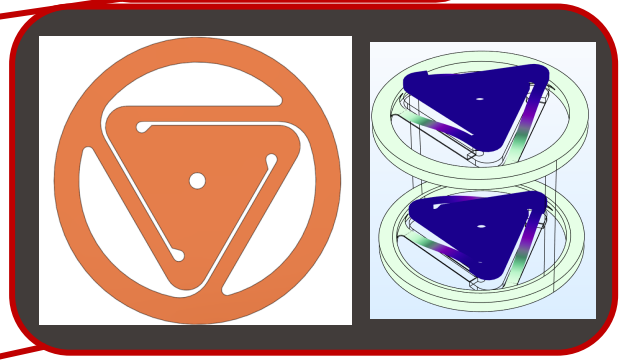












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Space application: Prototype of an Ultra Large Structure Assembly Robot (PULSAR)

video link

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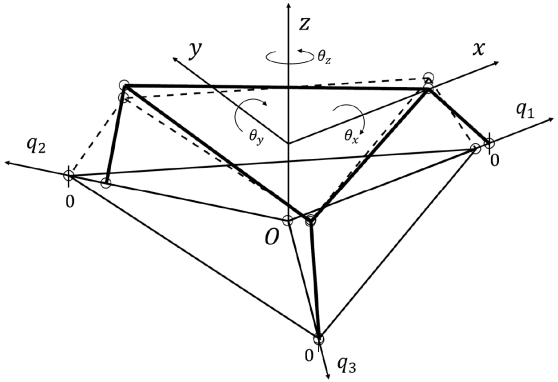
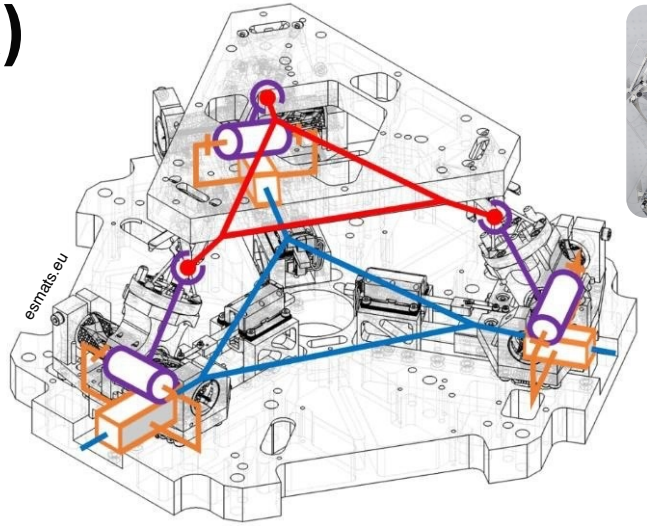
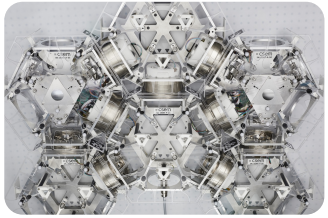
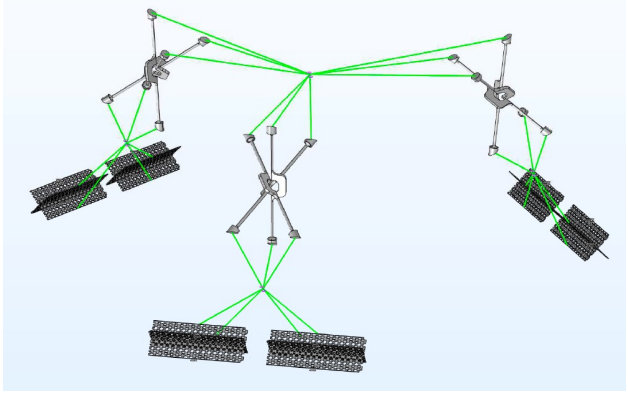


Schema of the PULSAR geometrical model





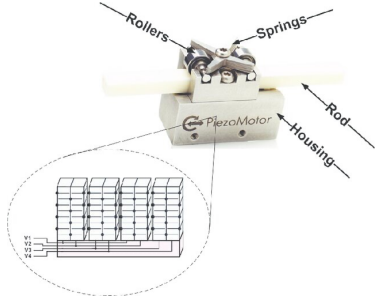
CAD of the PULSAR mechanism with its kinematic highlighted



FEA model of the PULSAR mechanism

Flex gimbal

Flex pivot



Piezoleg motor

DOI: 10.1109/CPE.2013.6601155

Astrophysics application: James Webb Space Telescope

video link

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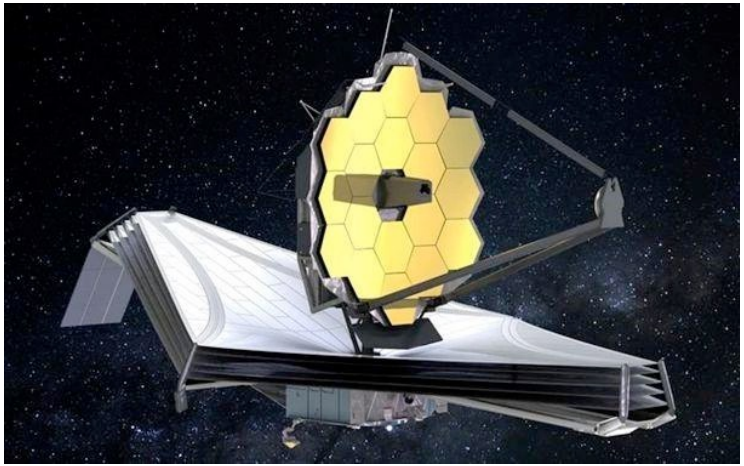

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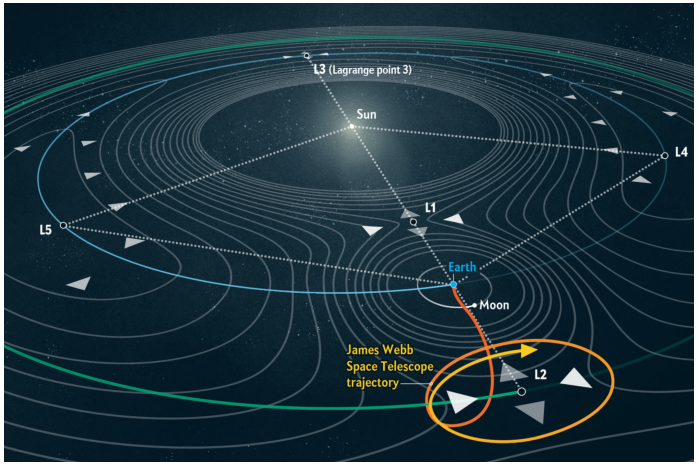
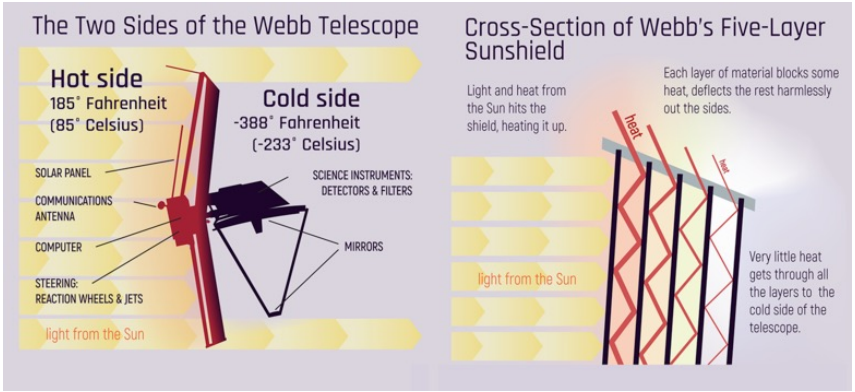


scientificamerican.com

JWST location at Lagrange point 2 (L2)



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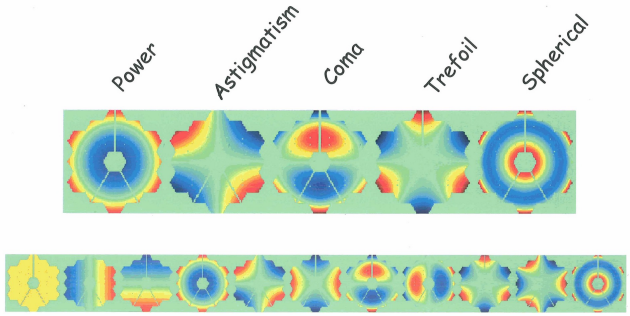
JWST thermal management

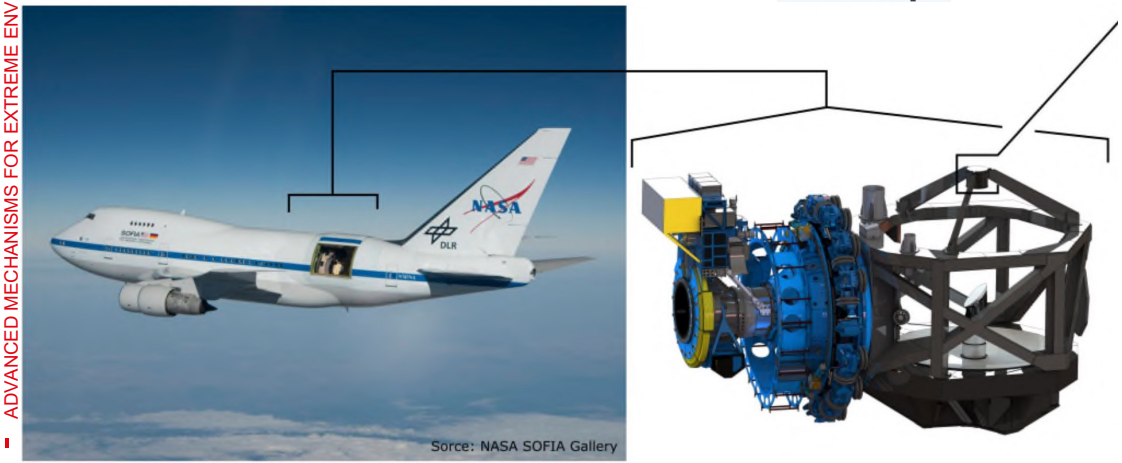


Zernike polynomials of JWST primary mirror alignment error

Astrophysics application: Stratospheric Observatory for Infrared Astronomy (SOFIA) Secondary Mirror Assembly

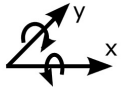
- 6 DoF hexapod for focusing, centring and tilting
  - Amplitude: ± 5 mm
  - Resolution: ≤ 0.5µm
- 2 DoF chopper stage for contrast
  - Amplitude ± 0.3° and frequency 0 - 20 Hz
- Dynamic pointing stability to account for turbulences

Aircraft **Telescope**

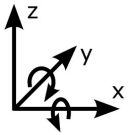


Hyperbolic Mirror (M2)

TCM
2 rotational degrees of freedom



FCM
3 translational degrees of freedom
+
2 rotational degrees of freedom



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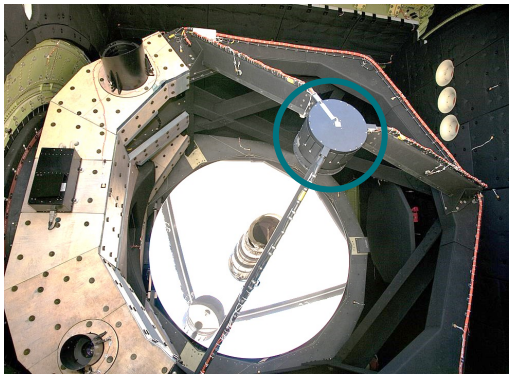

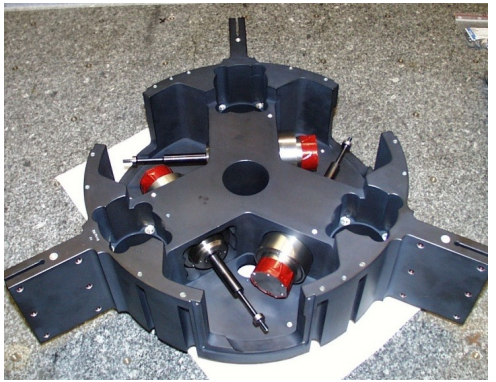

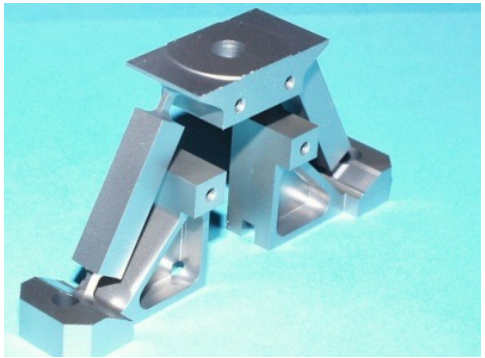

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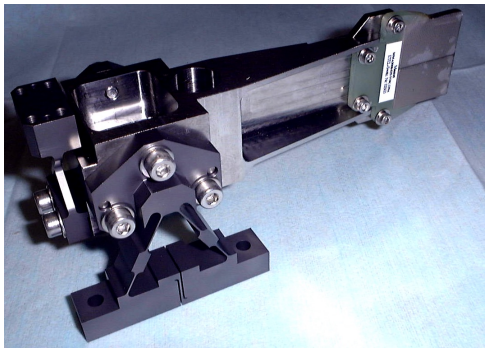
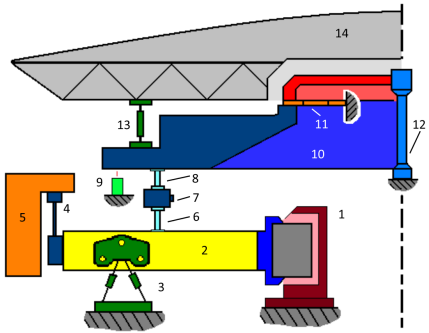




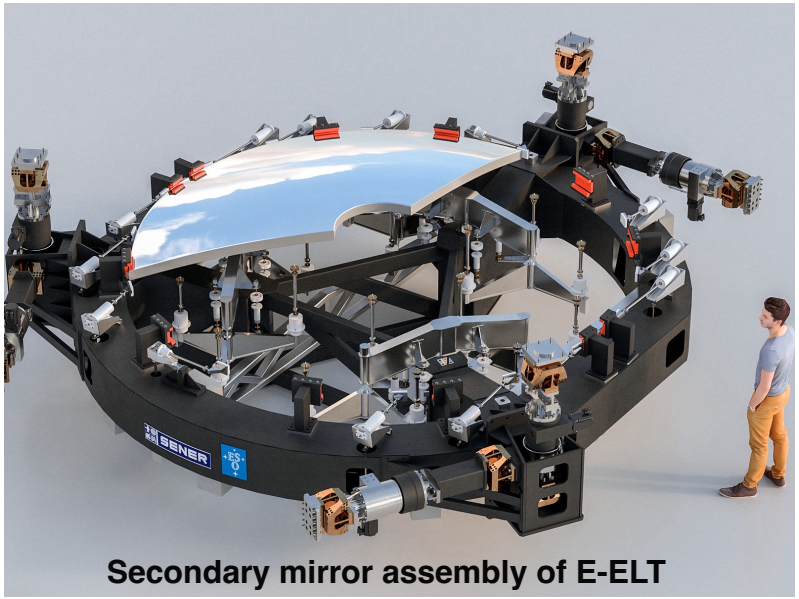
1. Linear Motor
2. Lever arm
3. Lever pivot
4. Compensation blade
5. Compensation ring
6. Pivot rod bottom
7. Force Sensor
8. Pivot rod top
9. Position Sensor
10. Mirror holder
11. Pivot membrane
12. Central pivot
13. Mirror bipod
14. Mirror

worldscientific.com

Astrophysics application: European Extremely Large Telescope (ESO E-ELT)

video link

Astrophysics application: European Extremely Large Telescope (ESO E-ELT)



Secondary mirror assembly of E-ELT

elt.eso.org

N. Dubost/Eduardo Garces/E. Garcés/ESO

E-ELT 80 m dome construction

Flash exercise:

Calculate the mechanical stress within the 3 vertical flexures in case of earthquake of magnitude 6 on Richter scale (2 g of Peak Ground Acceleration)

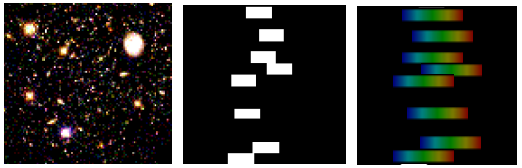
The flexures sections is 5 x 200 mm^2

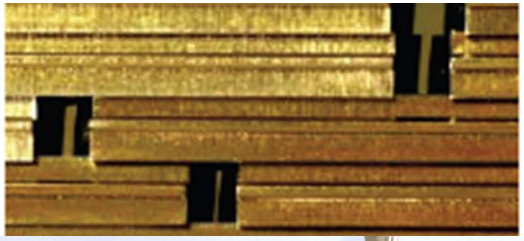
The secondary mirror assembly mass is 13 tons.

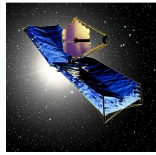
Astrophysics application: Cryogenic Slit-mask Unit (CSU) in Multi-Object Spectrograph for Infrared Exploration (MOSFIRE) on Keck I

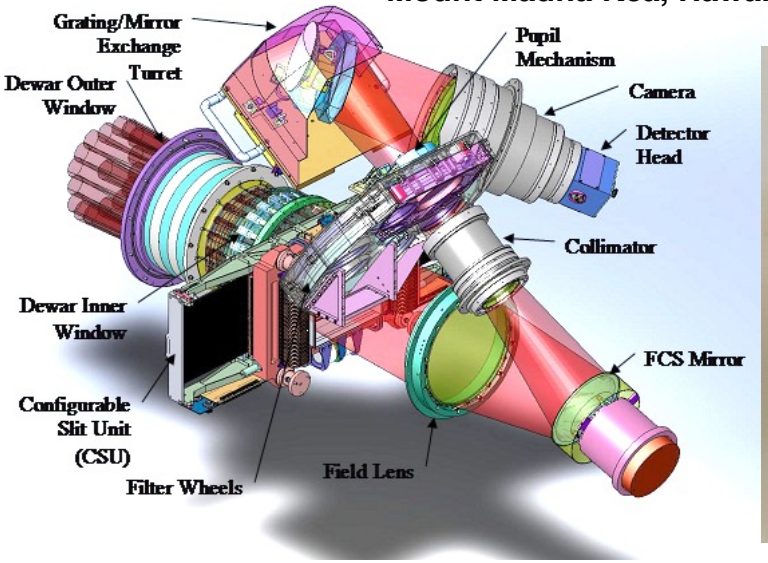
medium.com

Mount Mauna Kea, Hawaï









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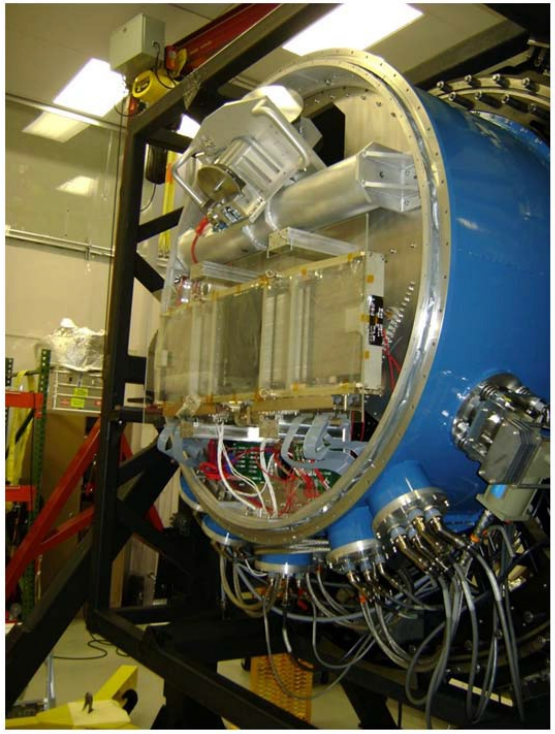
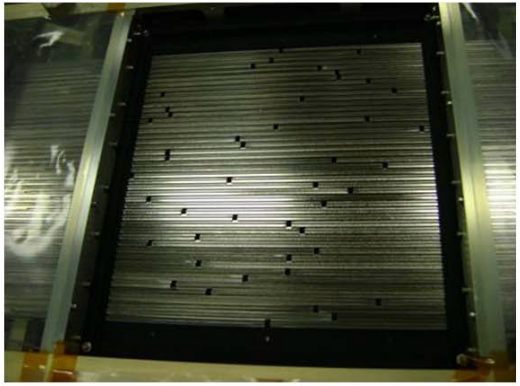
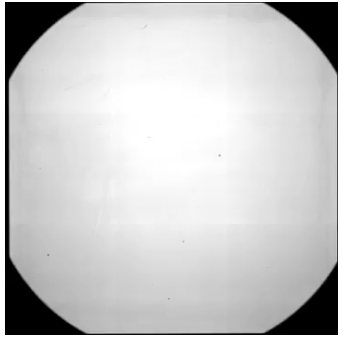
Astrophysics application: Cryogenic Slit-mask Unit (CSU) in Multi-Object Spectrograph for Infrared Exploration (MOSFIRE) on Keck I







McLean I. et al. Design and development of MOSFIRE, the Multi-Object Spectrometer For Infra-Red Exploration at the Keck Observatory, in Proc. of SPIE Vol. 7735, 2010

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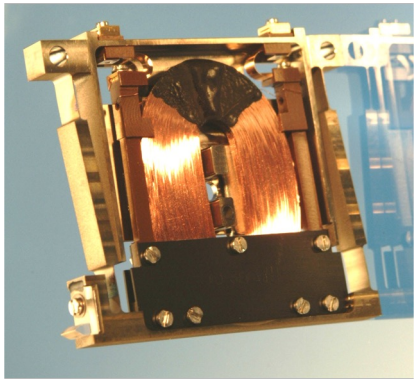
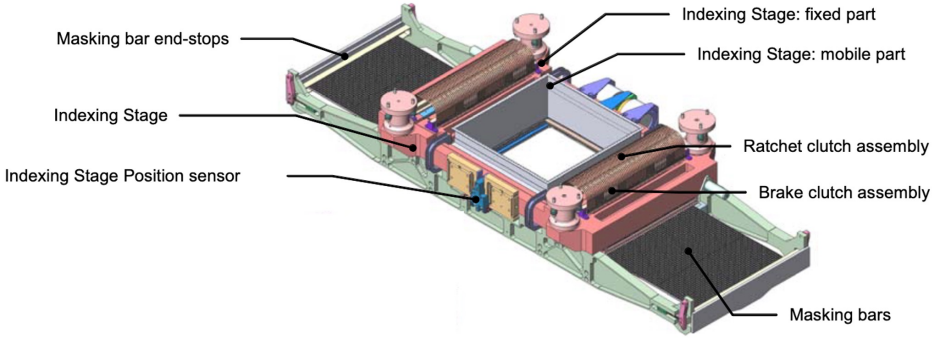
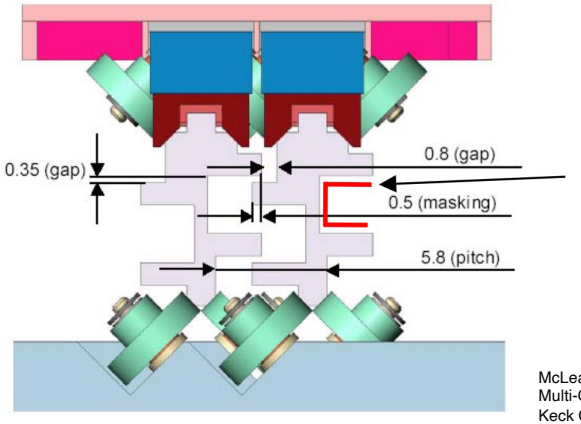
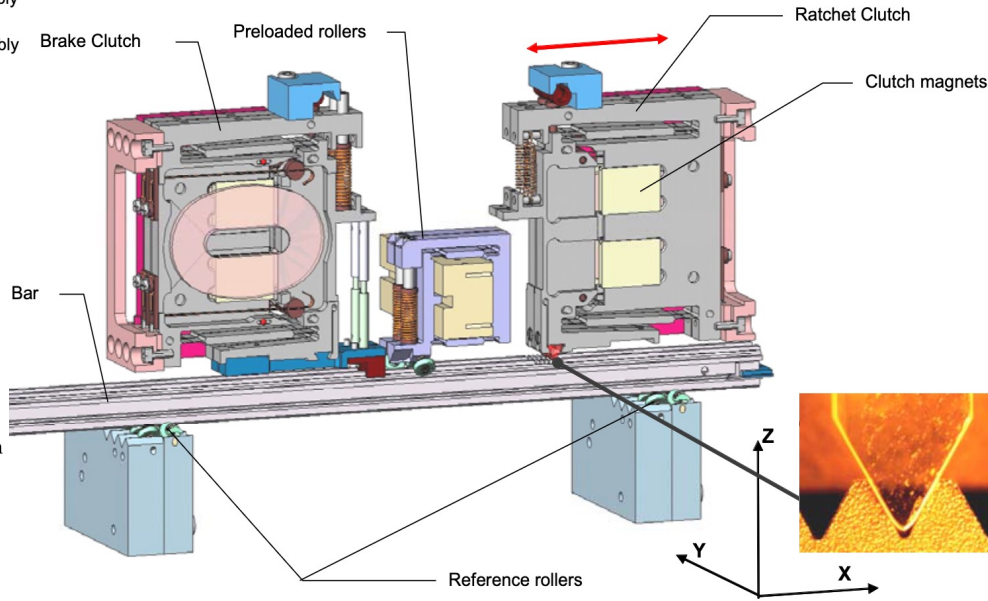






Area of additional low reflectance coating (both sides)



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MOSFIRE CSU

Week 1 exercises and homework

Exercise

- COMSOL basics tutorial on MOODLE : EXO_1_tuto_COMSOL.pdf
  - Connect to : VDI.EPFL.CH

- Additional tutorial if finished earlier:
  - https://www.comsol.com/model/bracket-8212-structural-mechanics-tutorials-10314
  - On MOODLE: models.sme.bracket_static-1.pdf
    bracket_static.mph
    bracket.mphbin

Homework

- Watch this video on FEA theory basics
  https://www.youtube.com/watch?v=GHjopp47vvQ

- And a COMSOL introductive video
  https://www.comsol.com/video/18-minute-introduction-to-comsol-multiphysics