UNIVERSITÀ DEGLI STUDI DI PADOVA

23 September 2025

INAF ISTITUTO NAZIONALE DI ASTROFISICA

TECH-PFA PhD Program
Admission to II year presentation

Multi-parametric thermal-mechanical modeling and analysis of high order active mirrors for space telescopes

Candidate: Chiara Scandaglia

Supervisors: Runa Briguglio, Marco Xompero

INAF - O.A. Arcetri

XL Cycle

Educational requirements

Attended courses

- **Adaptive Optics for Astronomy I** - Dr. Carmelo Arcidiacono - *Passed*
- **Adaptive Optics for Astronomy II** - Dr. Kalyan Radhakrishnan - *Attended*
- **Fundamentals of system engineering and project management for large scientific projects** - Dr. Marco Xompero and Dr. Runa Briguglio - *Passed*
- **Coupled electrical-thermal-structural Finite Element Analyses** - Dr. Michele Ballan, Prof. Giovanni Meneghetti and Prof. Mattia Manzolaro - *Passed*
- **Methodologies and techniques for the analysis of experimental data** - Prof. Alexis Pompili - *Attended*
- **Random excitations and response of structures** - Prof. Giuseppe Petrone and Prof. Francesco Franco - *Ongoing lectures*

- **12 total credits** (10 credits required from educational obligations)
- Missing exams will be taken **by the end of 2025**

Educational requirements

Planned schools and conferences

- **Workshop on Innovative Technologies for Space Optics (WITSO) 2025** - ESA/ESTEC, Noordwijk, The Netherlands - 13-17 October 2025 - **Workshop** - Poster accepted
- **SPIE Astronomical Telescopes + Instrumentation 2026** - Copenhagen, Denmark - 5-10 July 2026 - **Conference**
- **Observing with Adaptive Optics 2026** - Observatoire de Haute-Provence, Saint-Michel-l'Observatoire, France - October 2026 - **School**

A **period of study and research abroad** during the second year is foreseen, but not yet defined. The **ESA OSIP program** is one of the proposed options.

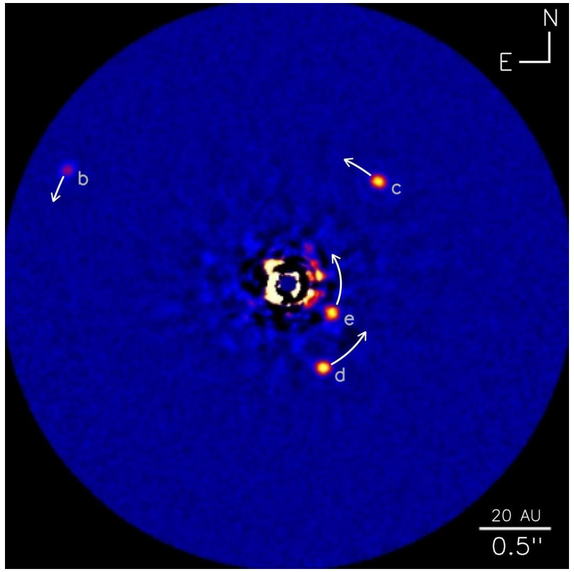
Scientific context

SCIENCE CASES → **REQUIREMENTS** → **TECHNOLOGIES**

- Earth-like exoplanets characterization
- Cosmological structures observation

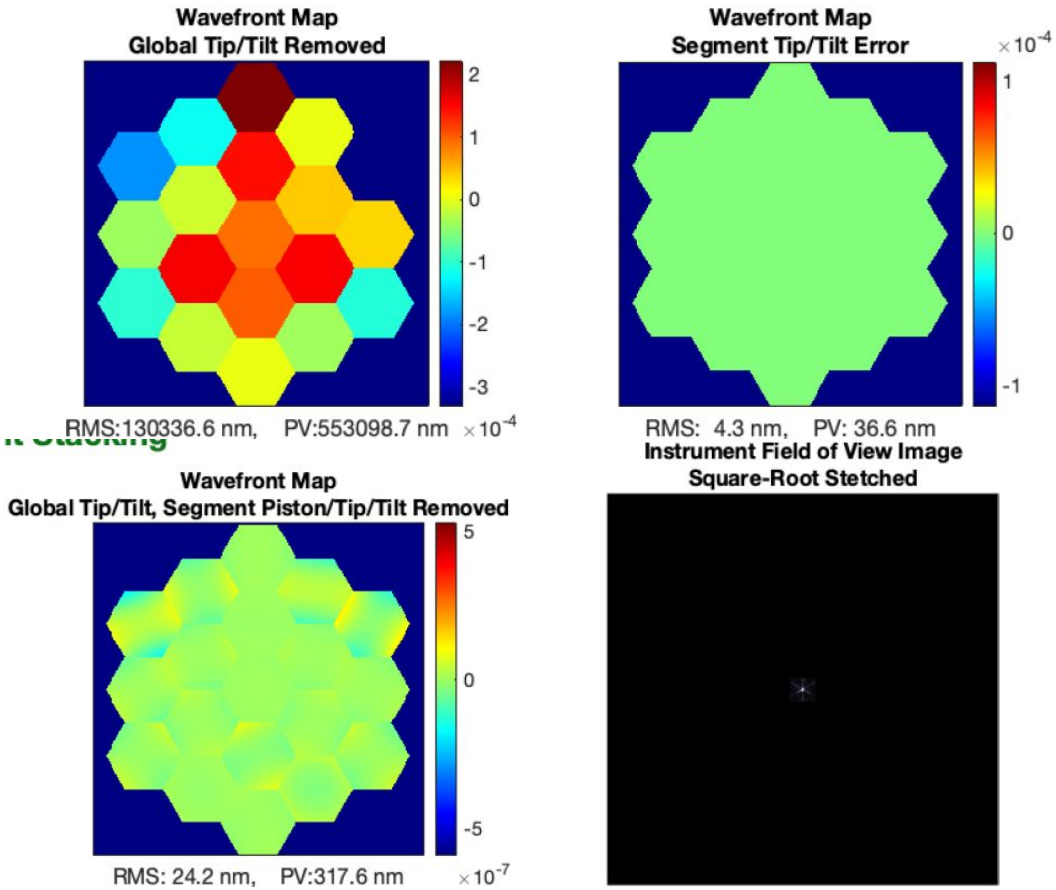
- High resolution
- High contrast
- Ultra-stable wavefront
- Risks and costs mitigation

- Large primary apertures
- Deformable mirrors (w/ contactless actuators)
- Wavefront sensors
- Active optics control loops



Why adaptive optics in space?

- **Features**
  - **Stable wavefront control**
  - **Large primary aperture achievable**
    - and correction **directly on the primary**
  - Support **vibration rejection** through the use of particular actuators (e.g. **voice coil**)
    - **Decoupling from the mirror**
    - Use of **lighter materials -> mass reduction**
    - **Looser tolerances**
  - **Thermal load deformation correction**
  - **High contrast imaging** (e.g. if combined with coronagraph instruments)



- **Challenging topics**
  - New studies on **adaptation of ground-based technologies in the space context**
  - **New mission profiles taking into account deformable mirrors**
  - **Cost effectiveness assessment**

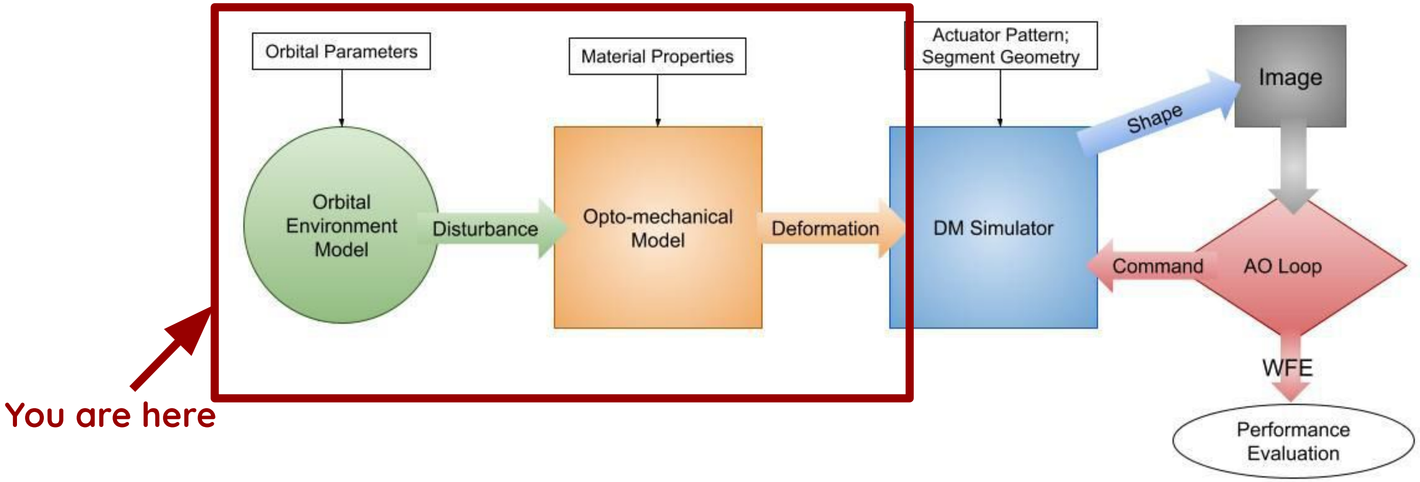
Main research activity
An active mirror system parametric integrated model

In what does it consists?

- **Telescope opto-mechanical model**
  - w/ **variable mirror configuration** parameters
- **Thermal-mechanical simulator**
  - w/ **variable orbital environment** parameters

TO

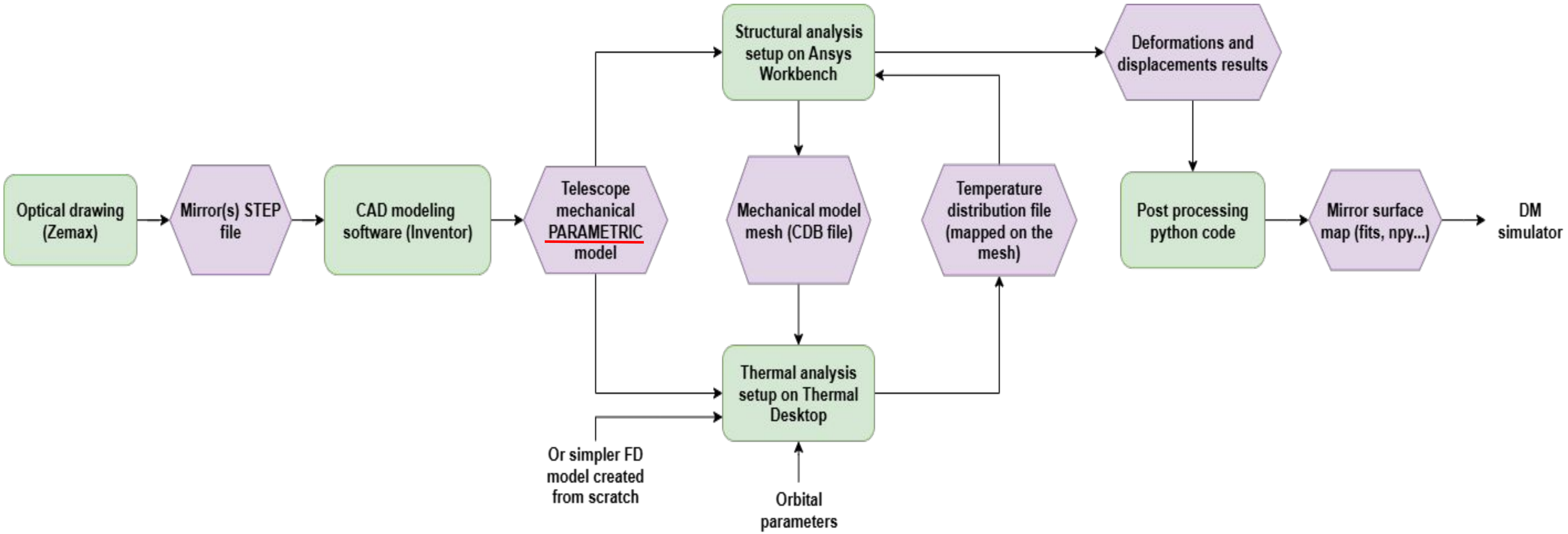
- Calculate **deformations and displacements**
- Compute **wavefront correction**
- Estimate **mirror performance** (fitting error)
- Set **trade-offs** and **optimize**
  - **mission profiles**
  - **mirror configurations**
- Evaluate the **system behaviour** in **different scenarios** (i.e. **costs**)



Leading question: with regard to typical space mission profiles, costs and requirements, **what could make this technology more attractive than others?**

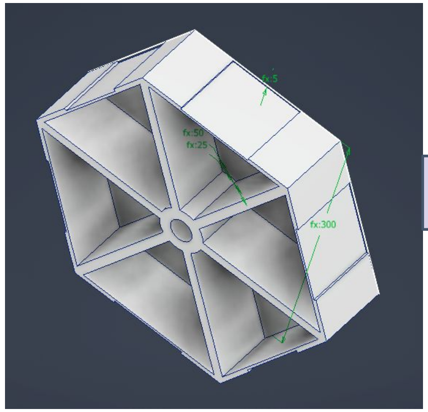
Part of the **ULAOPS** project, funded by ASI and in collaboration with PoliMi and industrial partners

Simulation pipeline

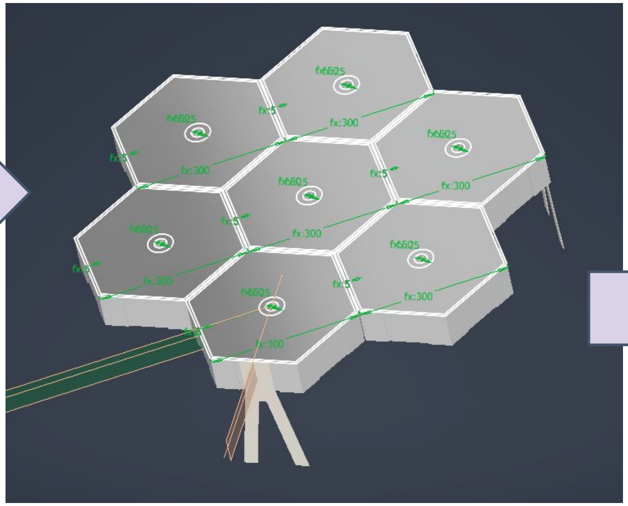


Simulation train meant to be as **automatized** as possible, to autonomously switch between the environmental condition and mirror configuration parameters and re-run the analysis

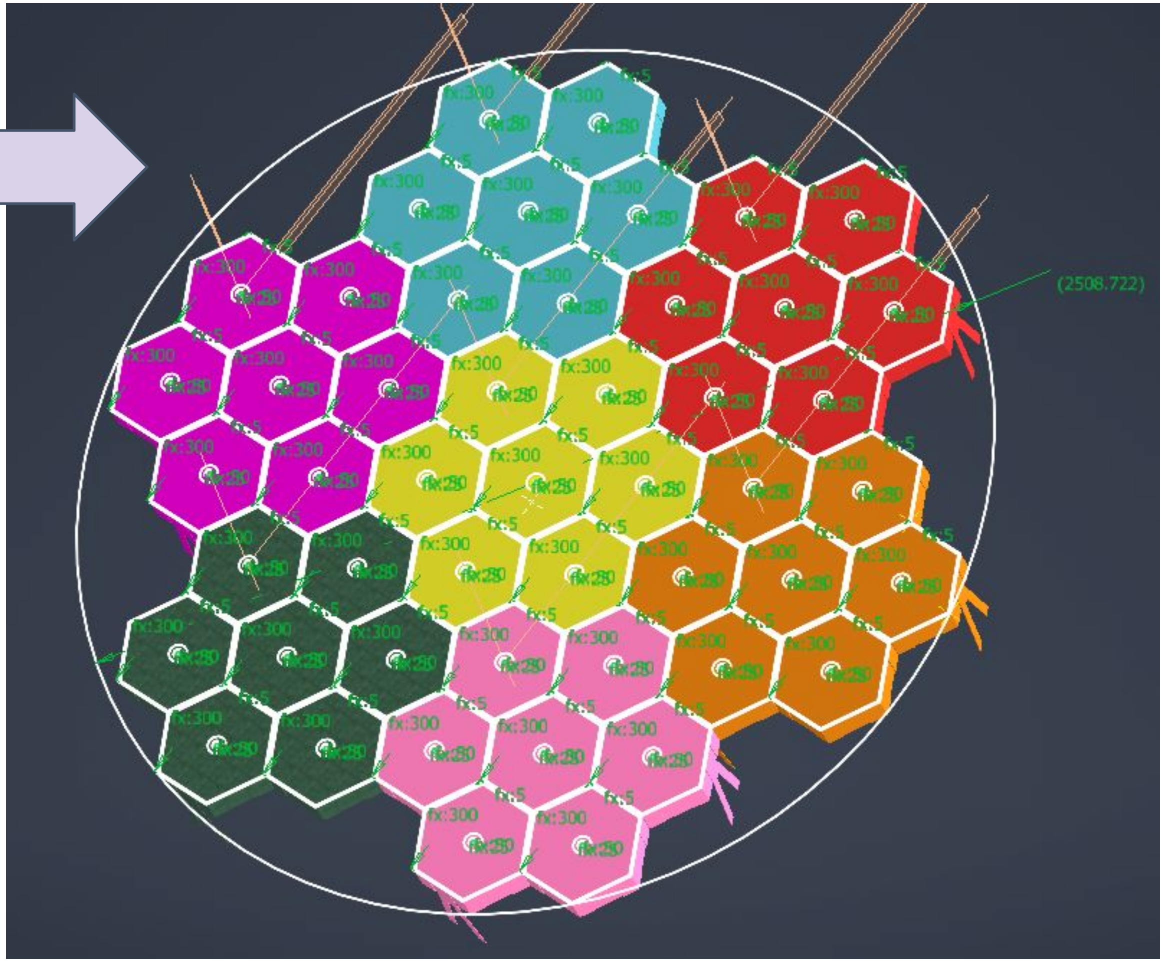
First implementations: structural parametric model



Single actuator cell model



Deformable mirror segment (module) support model with 7 actuator cells

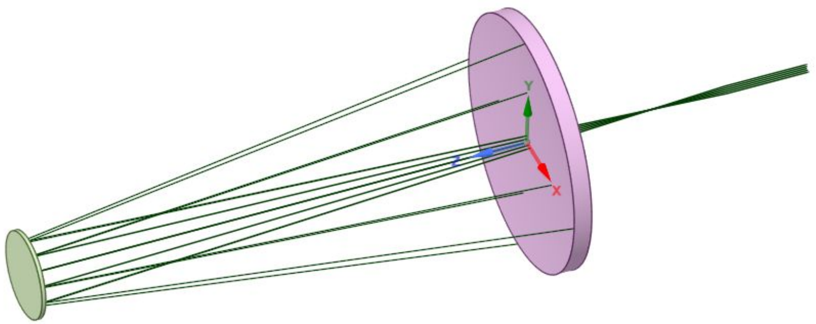


Deformable mirror support model with 7 modules

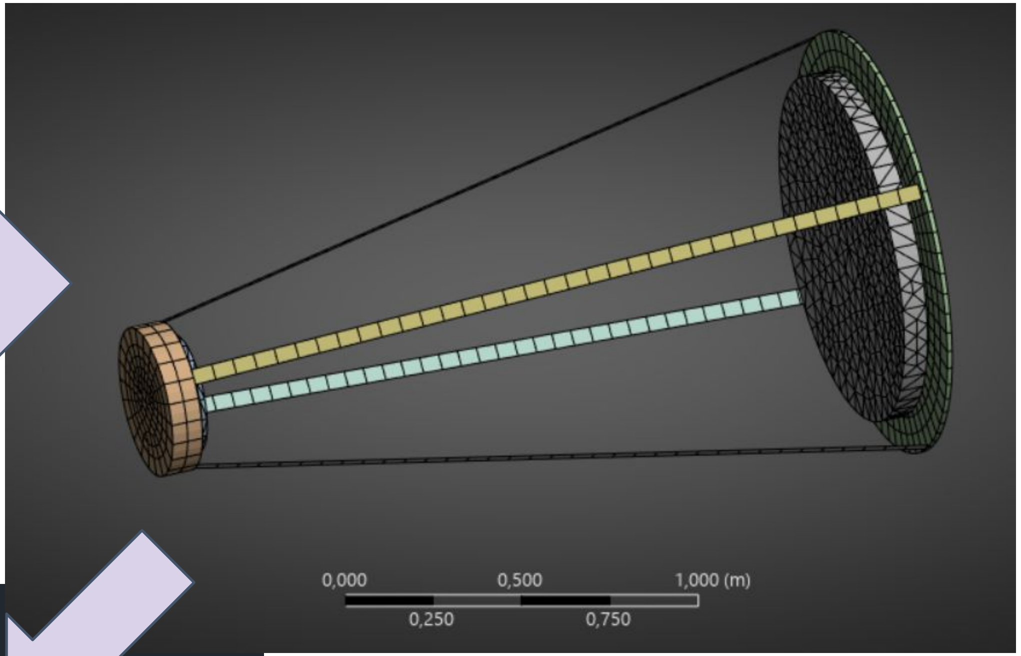
t	5	mm	parametri cellula
side	400	mm	
hole	25	mm	
height	80	mm	
n_pat1	3	ul	parametri modulo
d_pat1	402,88	mm	
delt_T	100		
CTE	2,4E-05	mm	
bipod_h	200	mm	structure
bipod_t	2	mm	
bipod_a	80	deg	

Configuration parameters

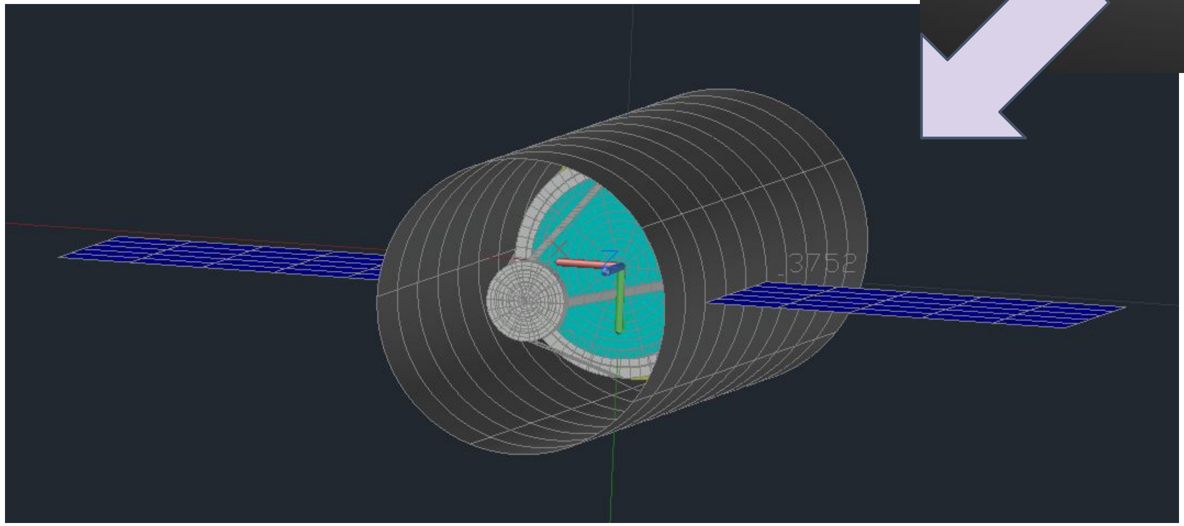
First implementations: thermal inputs on FEM model



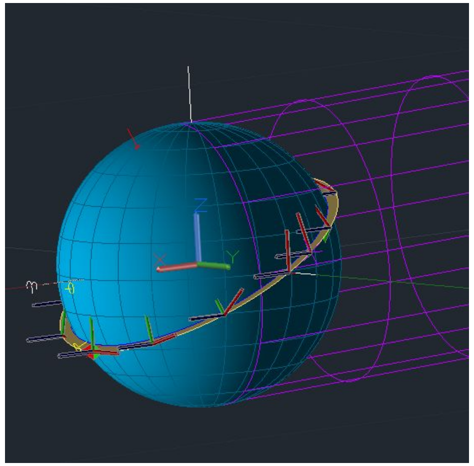
Telescope optical drawing



Telescope dummy mechanical model + mesh



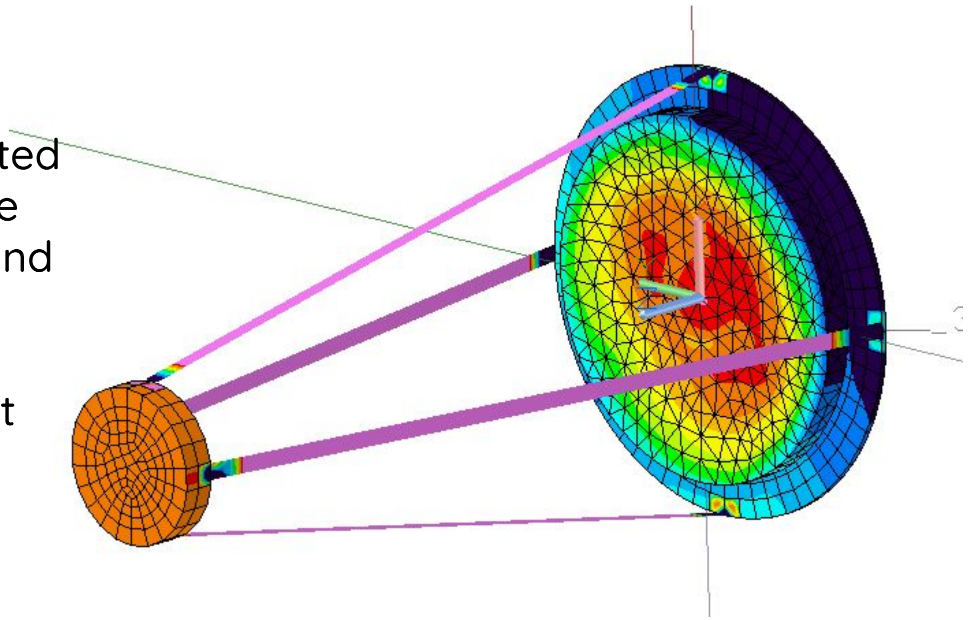
Telescope thermal model (inside a dummy spacecraft for thermal boundary conditions)

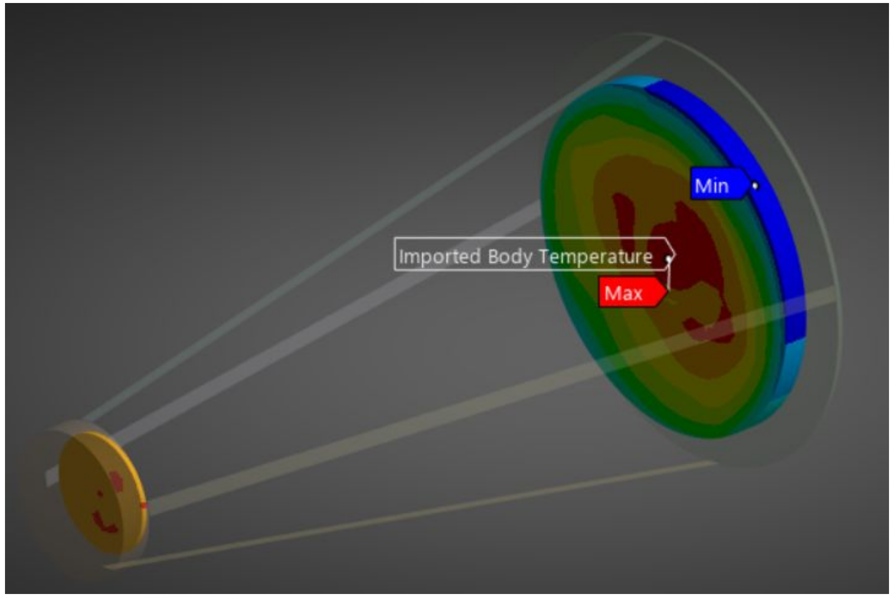


Selected orbit

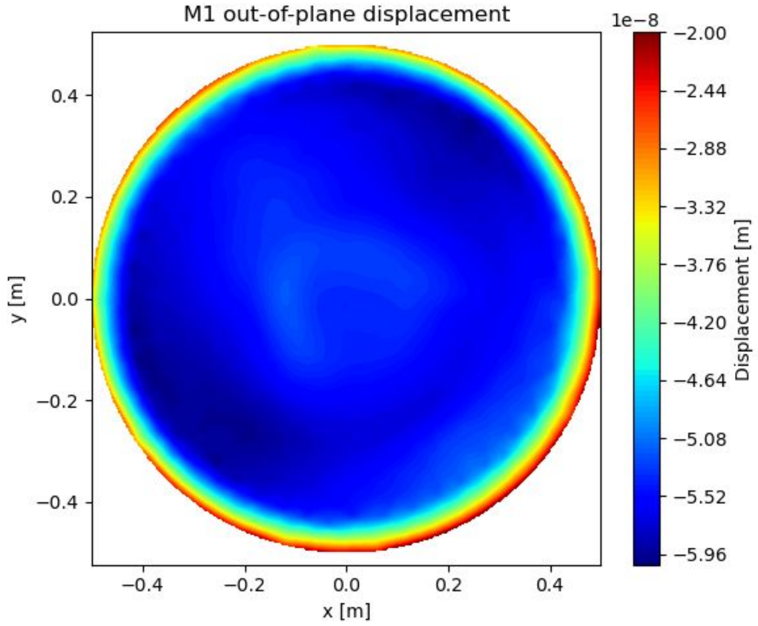
First implementations: thermal inputs on FEM model

FEM mesh imported in the telescope thermal model and temperature distribution mapped onto it

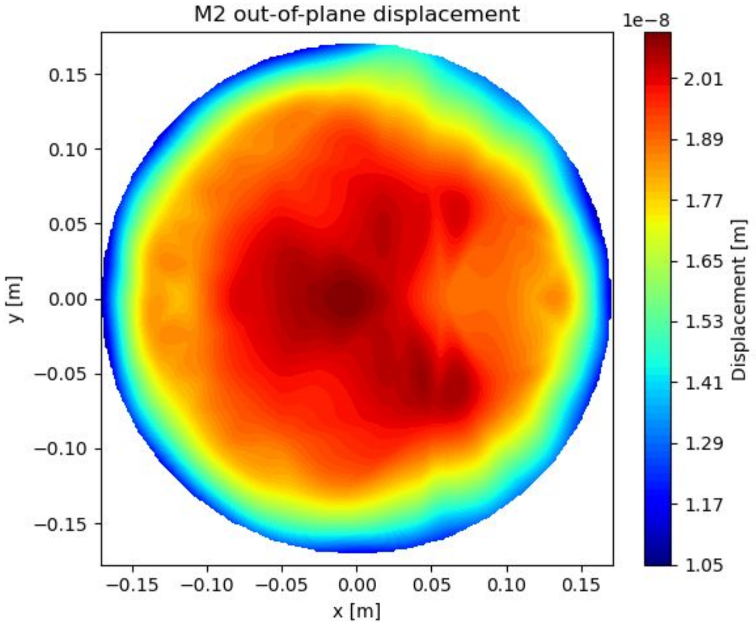




Imported temperature distribution in the Ansys Mechanical model

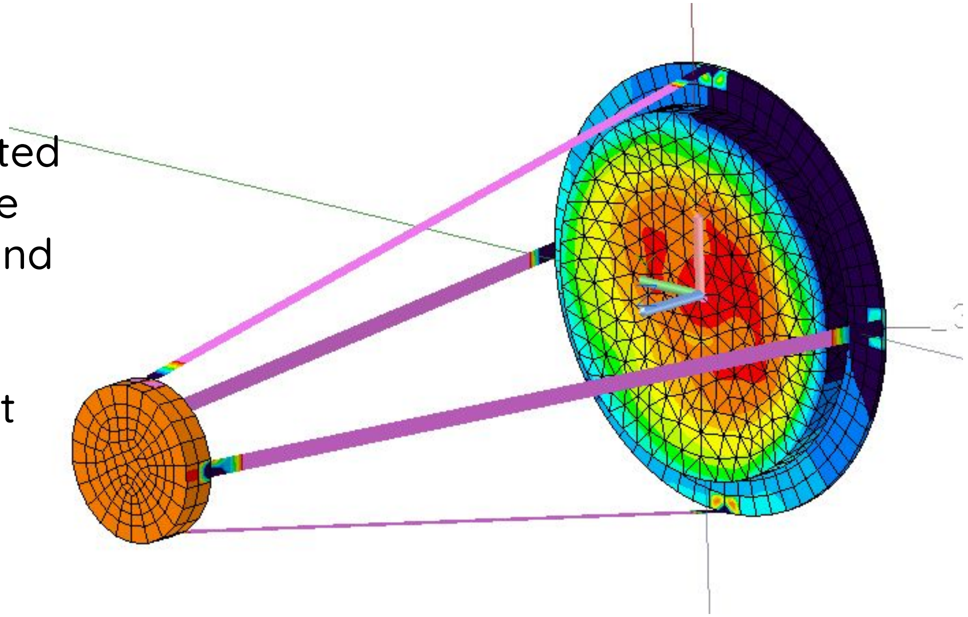


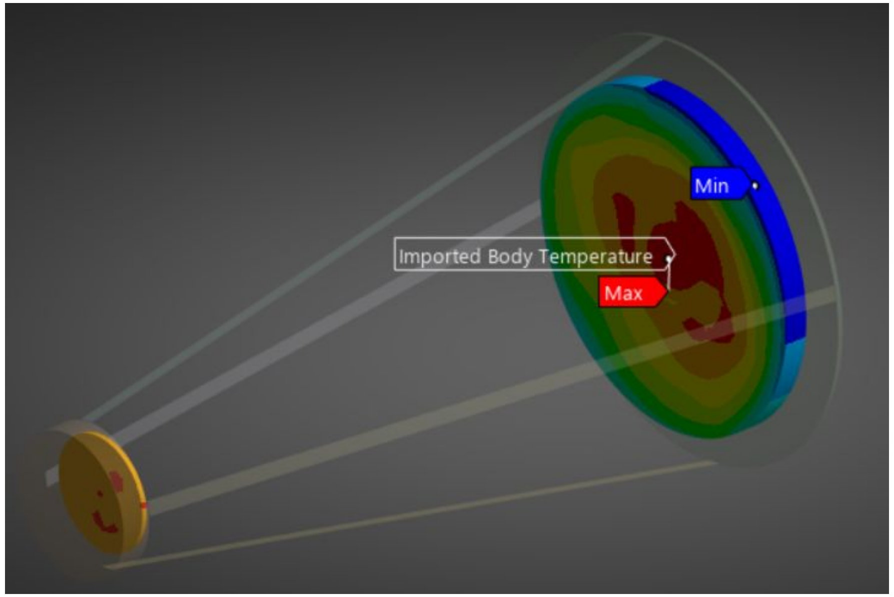
Out-of-plane displacements (WFE from deformations) calculated by Ansys and exported as python maps



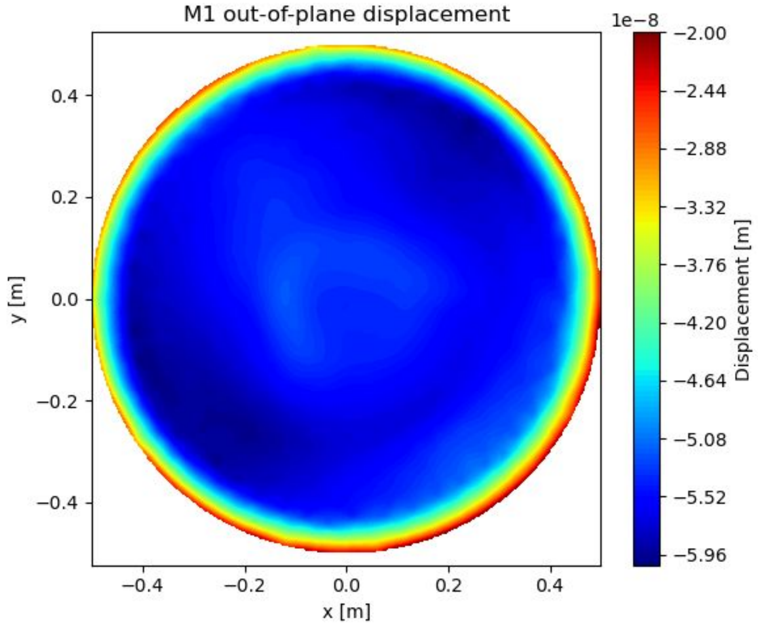
First implementations: thermal inputs on FEM model

FEM mesh imported in the telescope thermal model and temperature distribution mapped onto it





Imported temperature distribution in the Ansys Mechanical model



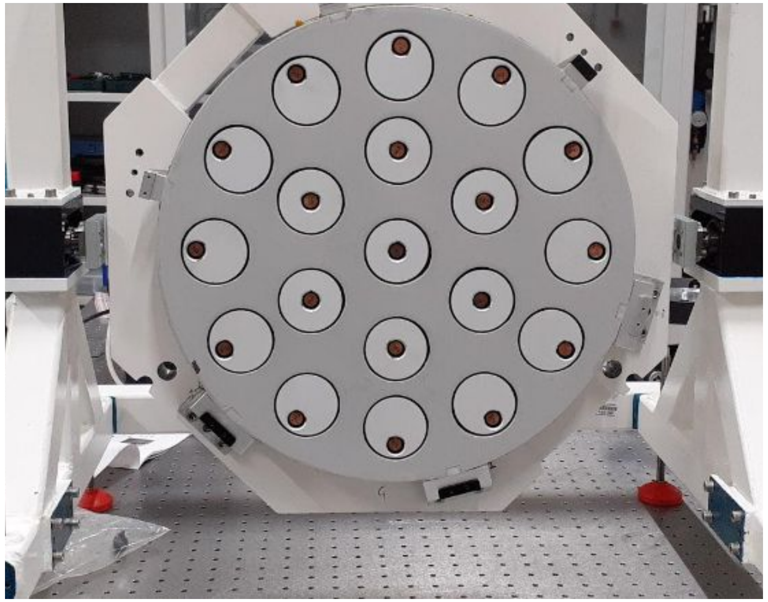
Out-of-plane displacements (WFE from deformations) calculated by Ansys and exported as python maps

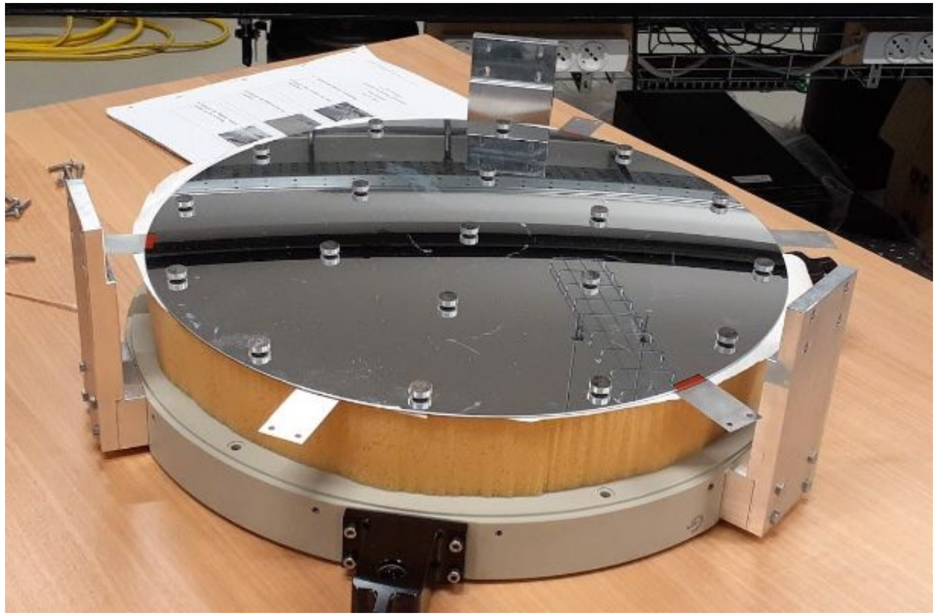
+sensitivity matrix·displacement vector

DM correction loop

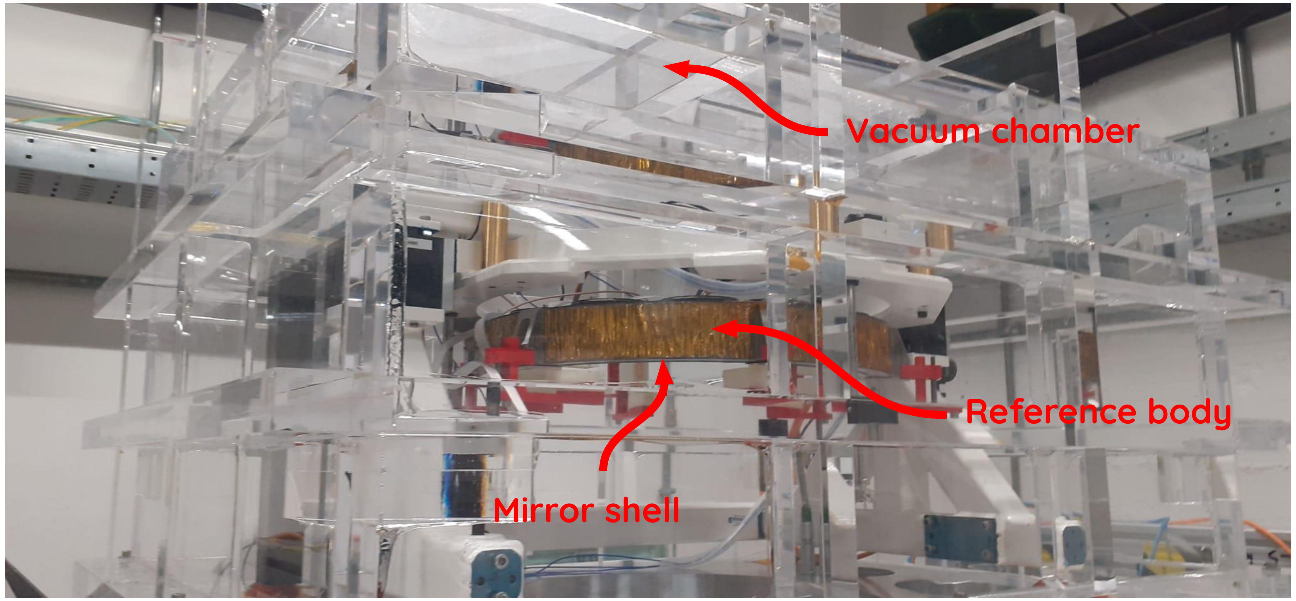
Other activities: introducing LATT

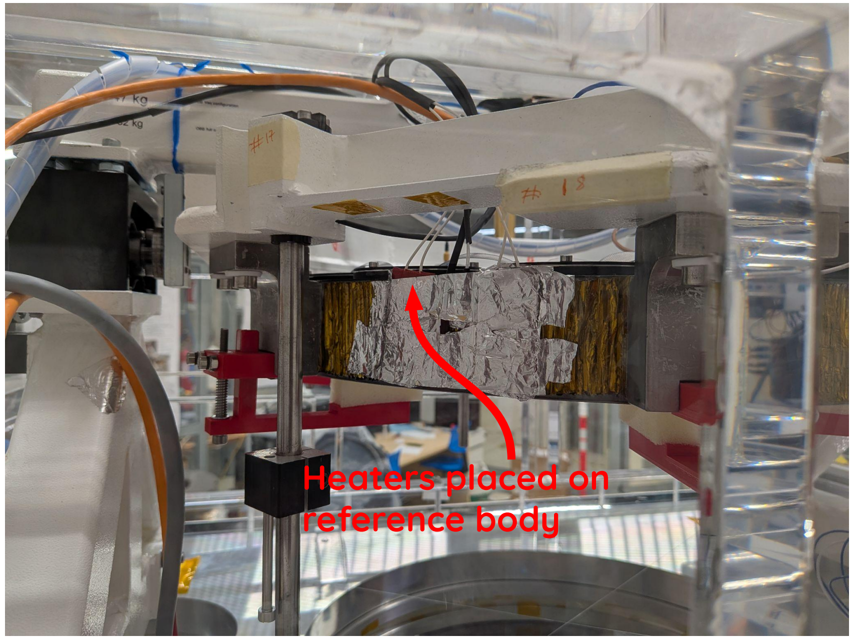
- **Deformable segment of a primary mirror** prototype
- **40 cm thin Zerodur deformable shell** (mirror)
- **Aluminium honeycomb reference body** (support)
- **Low mass density**
- 19 **voice-coil actuators** and 19 **capacitive sensors** (**contactless** technology)
  - When set, **the shell floats at a given gap from the reference body**
  - **Decoupling between mirror and support!**

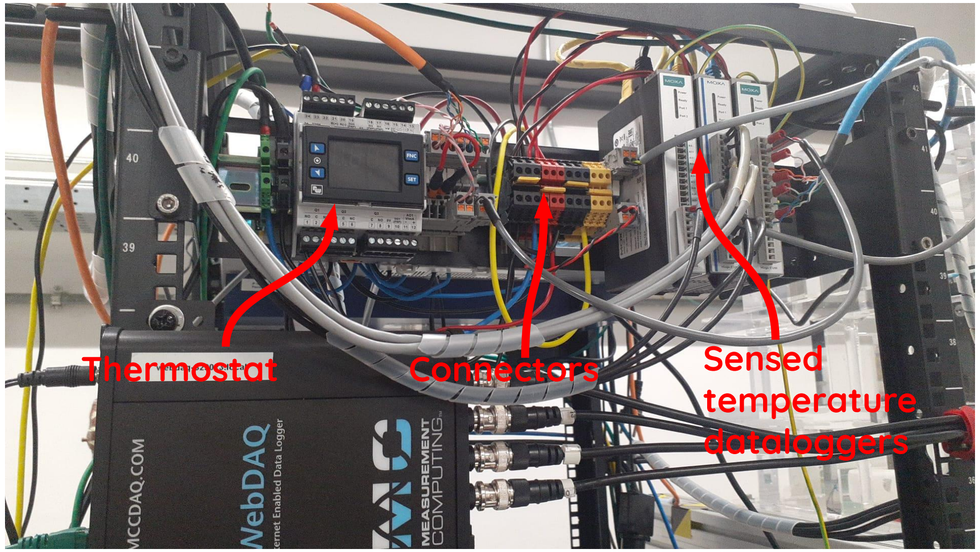


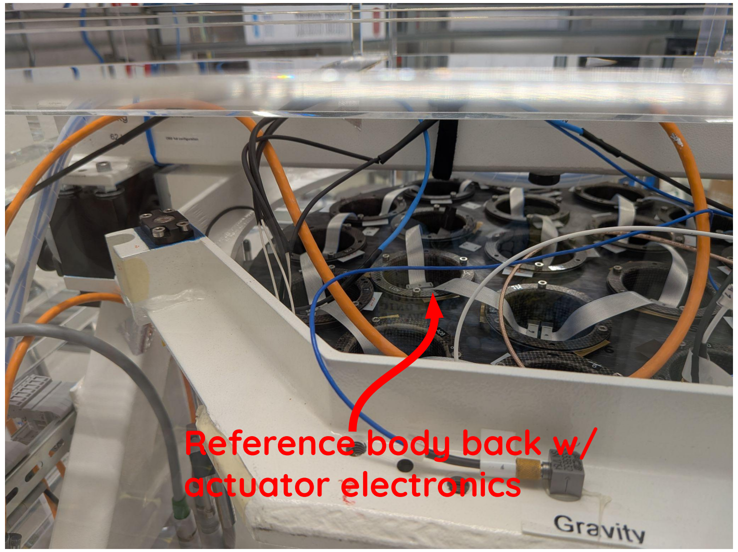


Other activities: LATT thermal tests



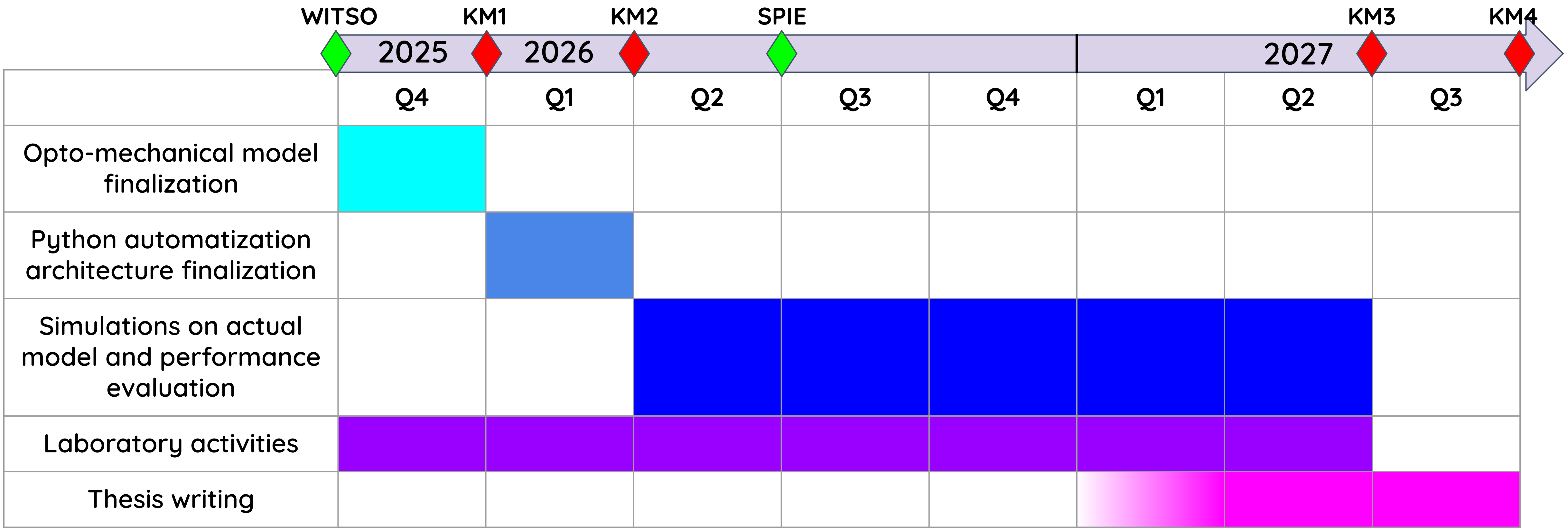






Goal: assess effects of **reference body deformations** and resulting **actuator commands** on **mirror correction**

Roadmap for the next years



MILESTONES

- **WITSO @ ESA** - Simulation scheme finalized
- **KM1** - Model completed
- **KM2** - Architecture code completed
- **SPIE @ Copenhagen** - Paper ready
- **KM3** - Activities completed
- **KM4** - Thesis completed

THANK YOU FOR YOUR ATTENTION!