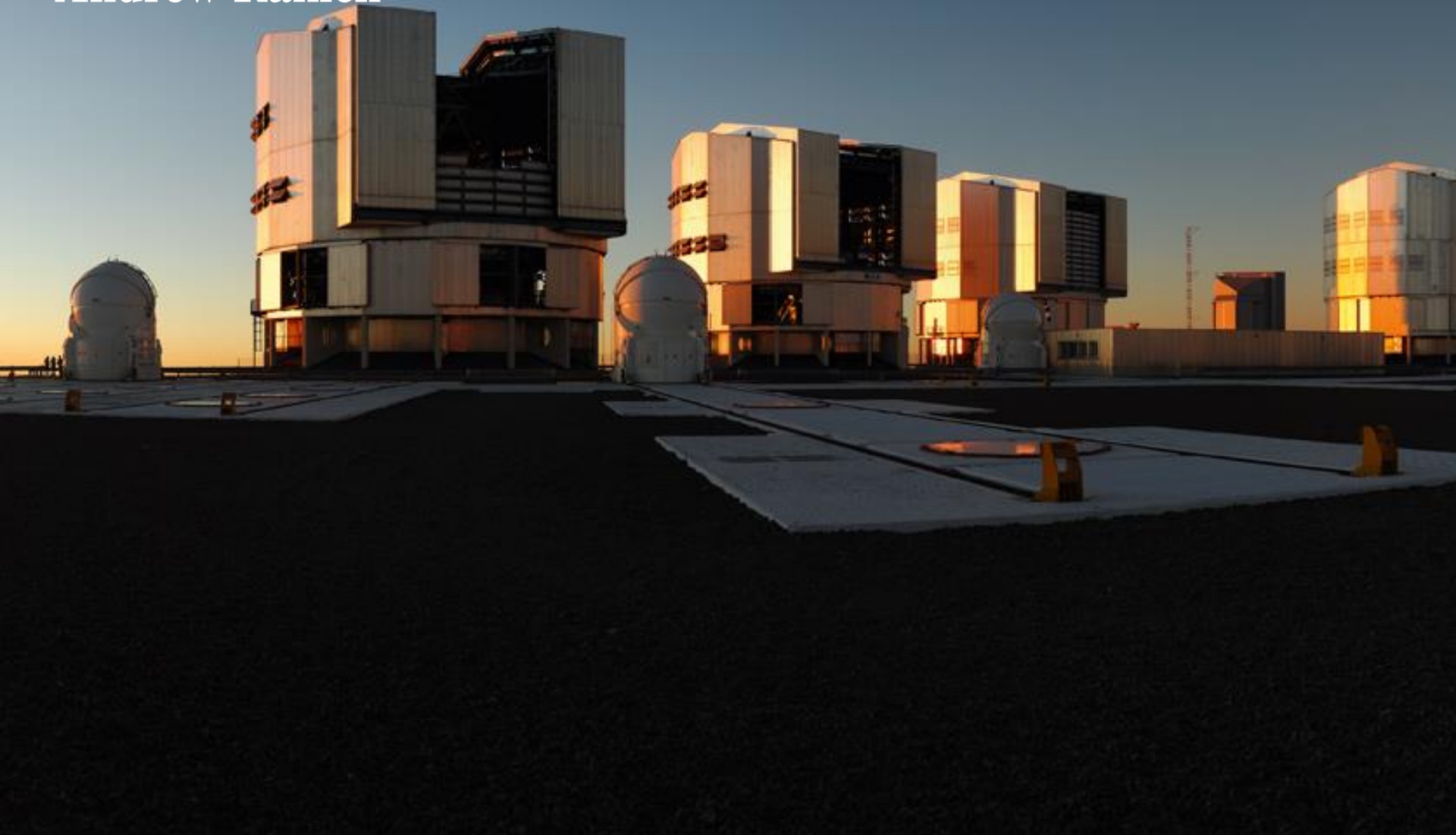


Overview of Advanced Materials and Surfaces activities at ESO

Andrew Rakich



ESO: the European Southern Observatory

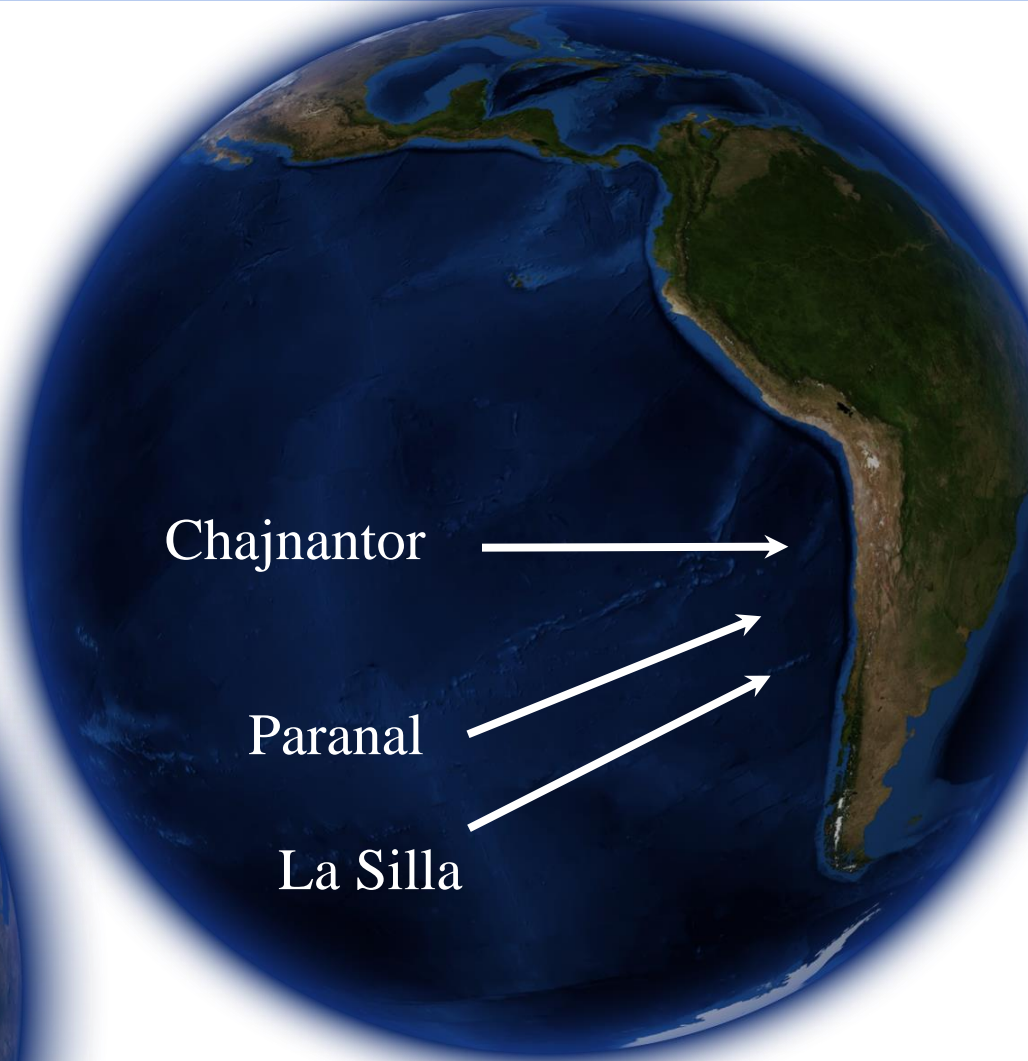
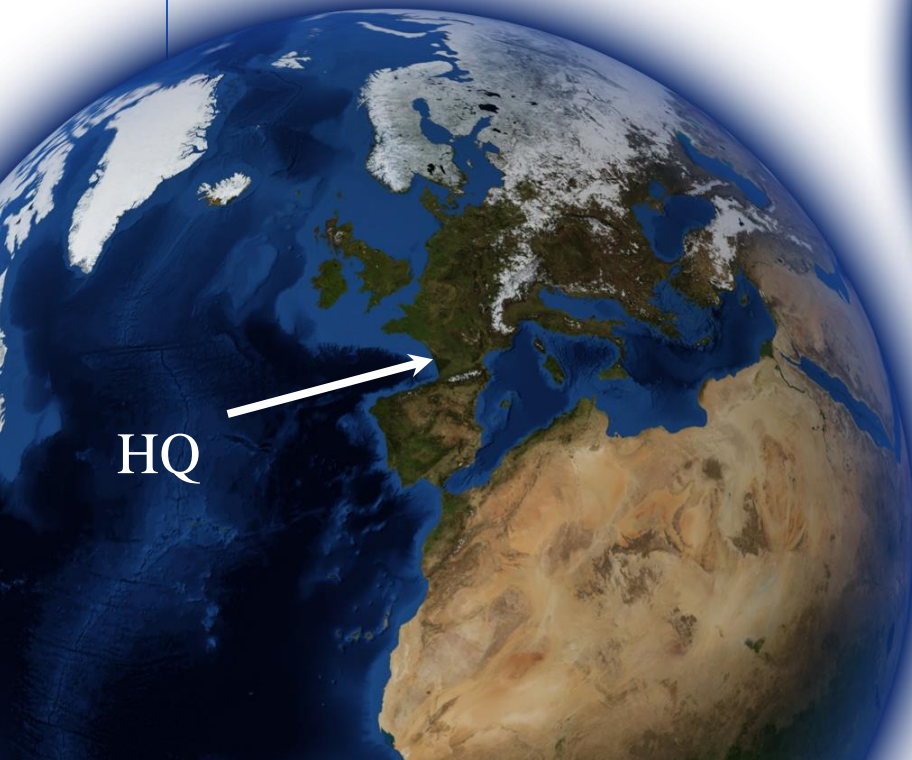
- [ESO](#) is the European Organisation for Astronomical Research in the Southern Hemisphere
- It was created in 1962
- Its member states are Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland, the United Kingdom and recently Brazil.
- ESO's headquarters are in Germany, in Garching near Munich
- ESO currently operates observatories at three sites in Chile
- European leadership in g-b astronomy (excl. Solar astronomy, Cerenkov...)



Three Directorates
with about 800 staff

ESO's observatory sites in Chile

- [Paranal](#) (2600 m)
- [La Silla](#) (2400 m)
- [Chajnantor](#) (5000 m)

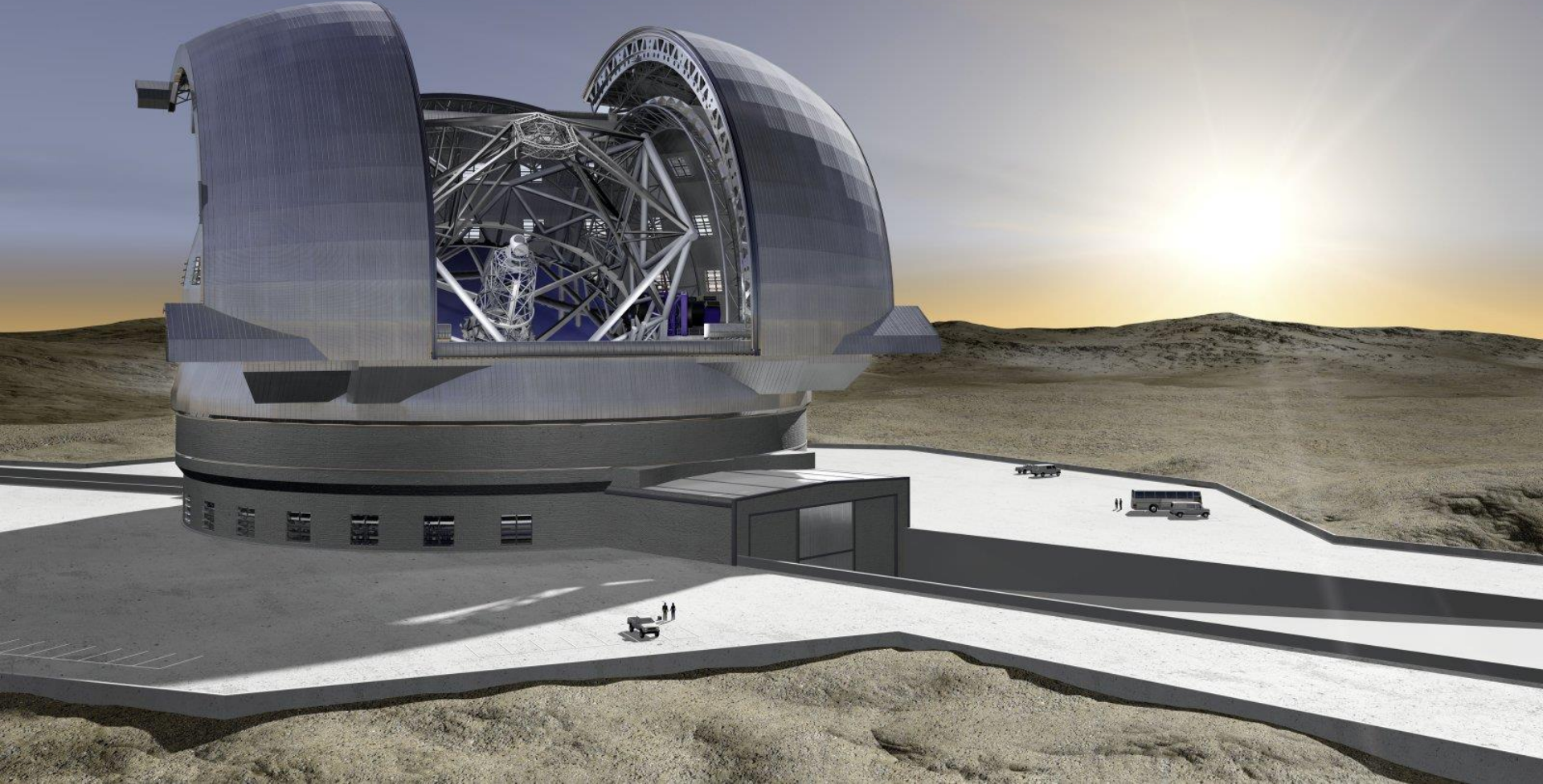


Paranal and the ESO VLT

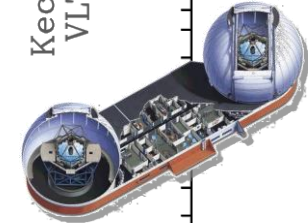
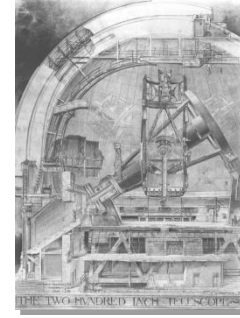
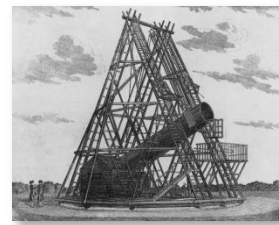
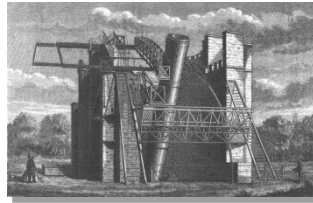
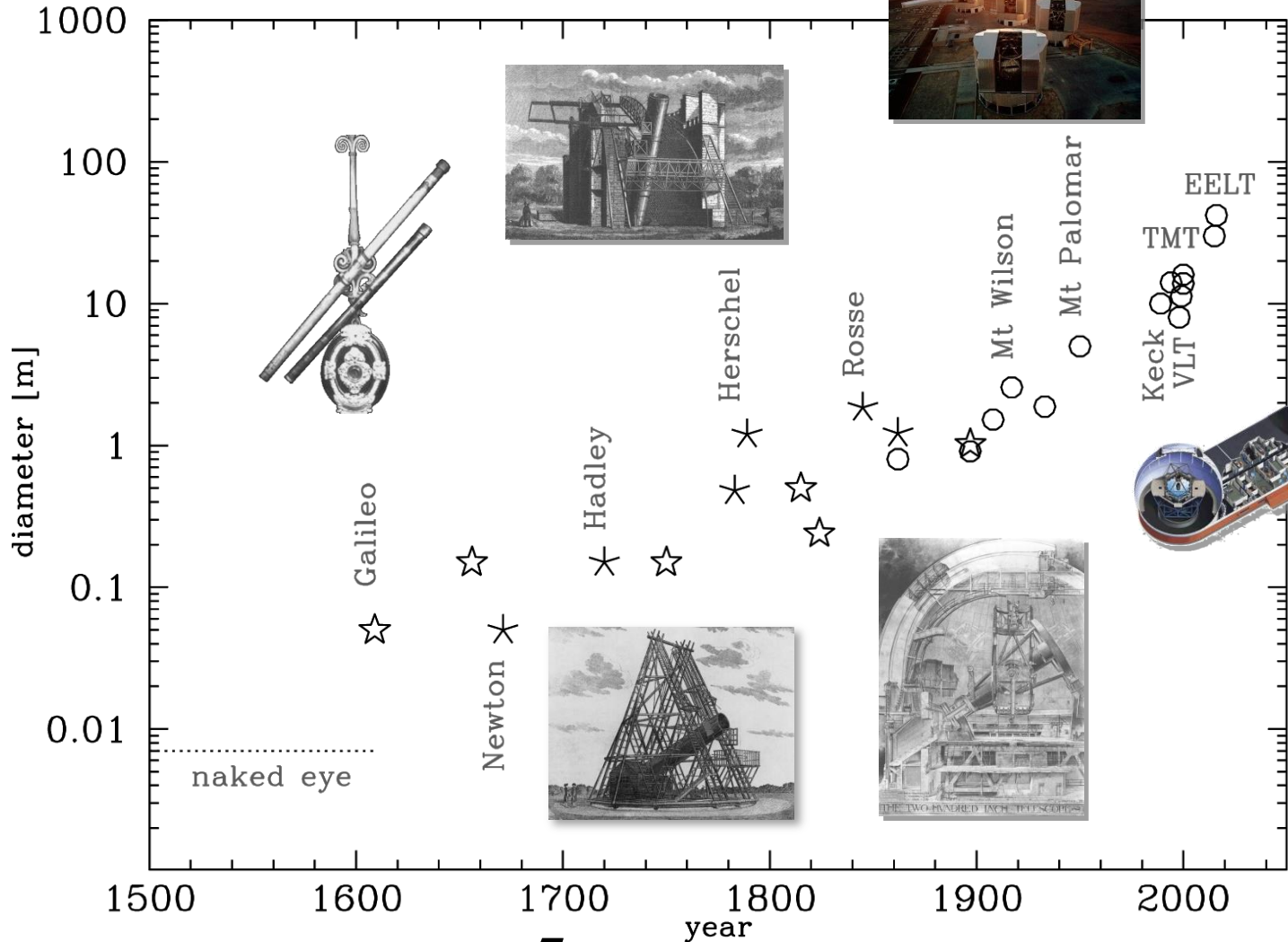
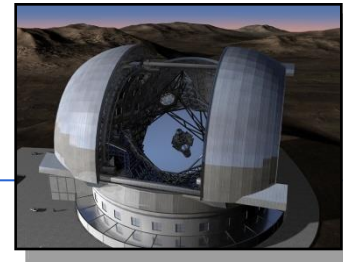




European Extremely Large Telescope



Technology in Astronomy



ESO Optical Components: Areas of Interest

ESO has numerous and varied requirements for optical components and metrology.

- 798 1.4 m diameter, off-axis aspheric, hexagonal mirror segments for E-ELT.
- The world's largest convex aspheric telescope mirror (E-ELT M2).
- Optics ranging down to tens or hundreds of microns in size (e.g. Shack Hartmann arrays).
- Optical components with surfaces ranging in complexity from simple spheres to aspheric surfaces that push the boundaries of current manufacturing technology.
- Optical metrology systems for:
 - Verification of manufactured components.
 - Laboratory alignment and testing.
 - *In situ* alignment.
 - Closed loop active optics.
 - photometric and spectro-photometric performance.
- A wide variety of optical coating requirements.
- Special optical materials for transmissive optics and mirror substrates.

ESO Optical Components: Surface finishing

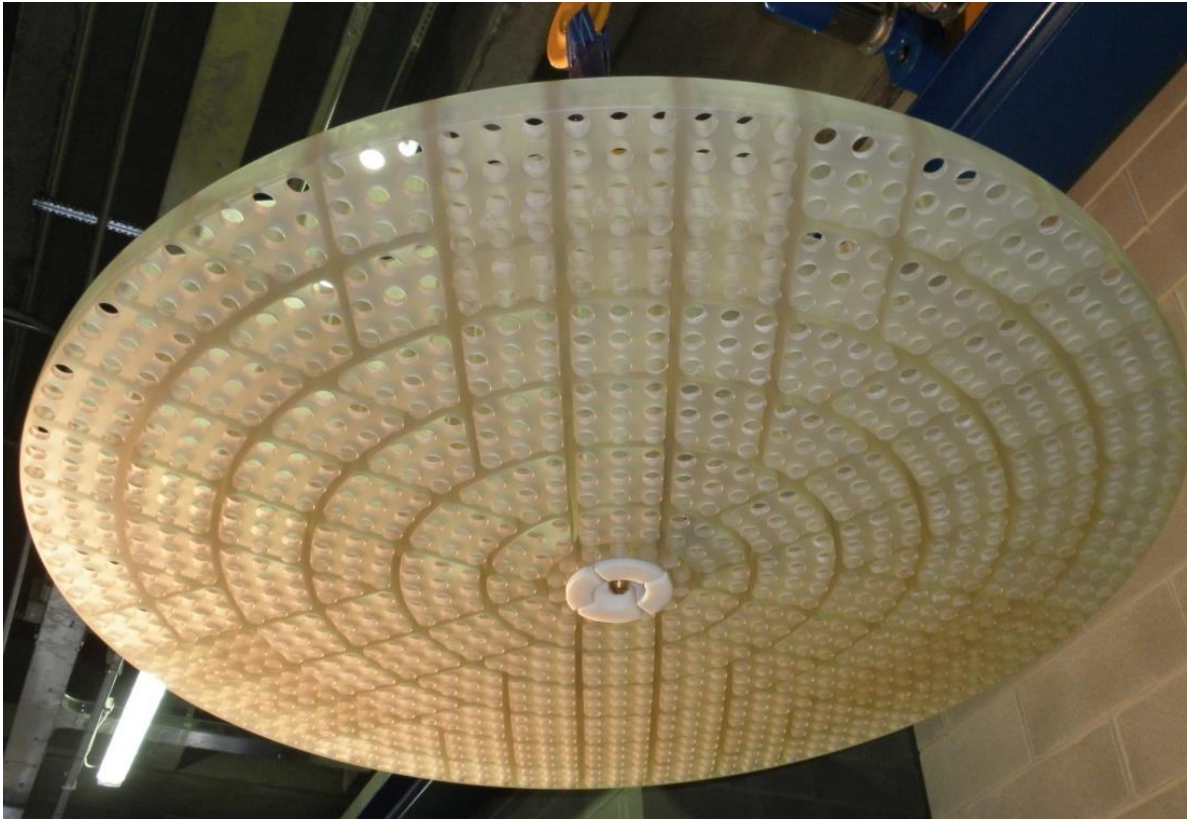
High quality optical surfaces are required for ESO telescopes and instrumentation.

- Typical allowed manufactured surface residuals of 10's of nanometers.
- Manufactured surface residual requirements often separated in the spatial frequency domain. Targets given for:
 - low spatial frequency
 - mid spatial frequency
 - high spatial frequency
 - very high spatial frequency (micro-roughness).
- High standards for cosmetic quality.

Manufacturers selected for ESO optical fabrication contracts are able to demonstrate:

- Mature and deterministic process control.
- Strong capability in optical metrology: test design, test environmental stability, error analysis, suitable test equipment etc.
- Well developed systems engineering and project management processes.
- Preferably demonstrated success in the production of similar components.
- Competitive pricing.

Special optics for AO



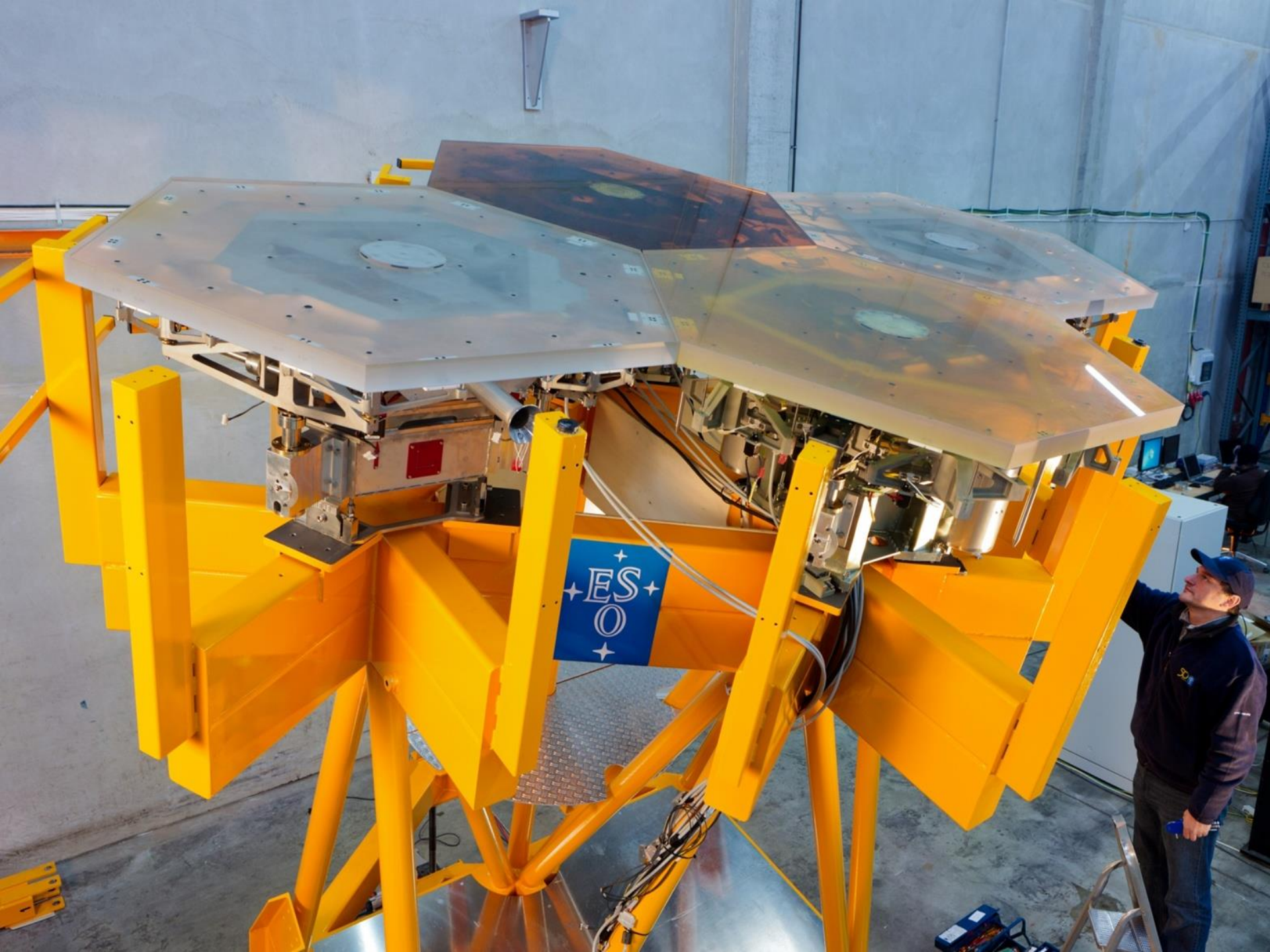
1.1 m light-weighted reference body for the VLT
Deformable secondary mirror



ESO Optical Components: Optical Products and Materials

Specialized optical materials and products are required for ESO telescopes and Instrumentation.

- Very low expansion glassy ceramics for mirror substrates, in sizes ranging up to 8 m diameter.
- Specialist optical glasses, often with high quality requirements on homogeneity of refractive index, and often with large (non-standard) diameters.
- Glasses and crystals with abnormal relative partial dispersion, allowing the simplification and performance enhancement of optical designs.
- Many ESO instruments are spectrographs; interest in gratings, large prisms, volume phase holographs.
- Phase and reflection holograms for optical testing and alignment.

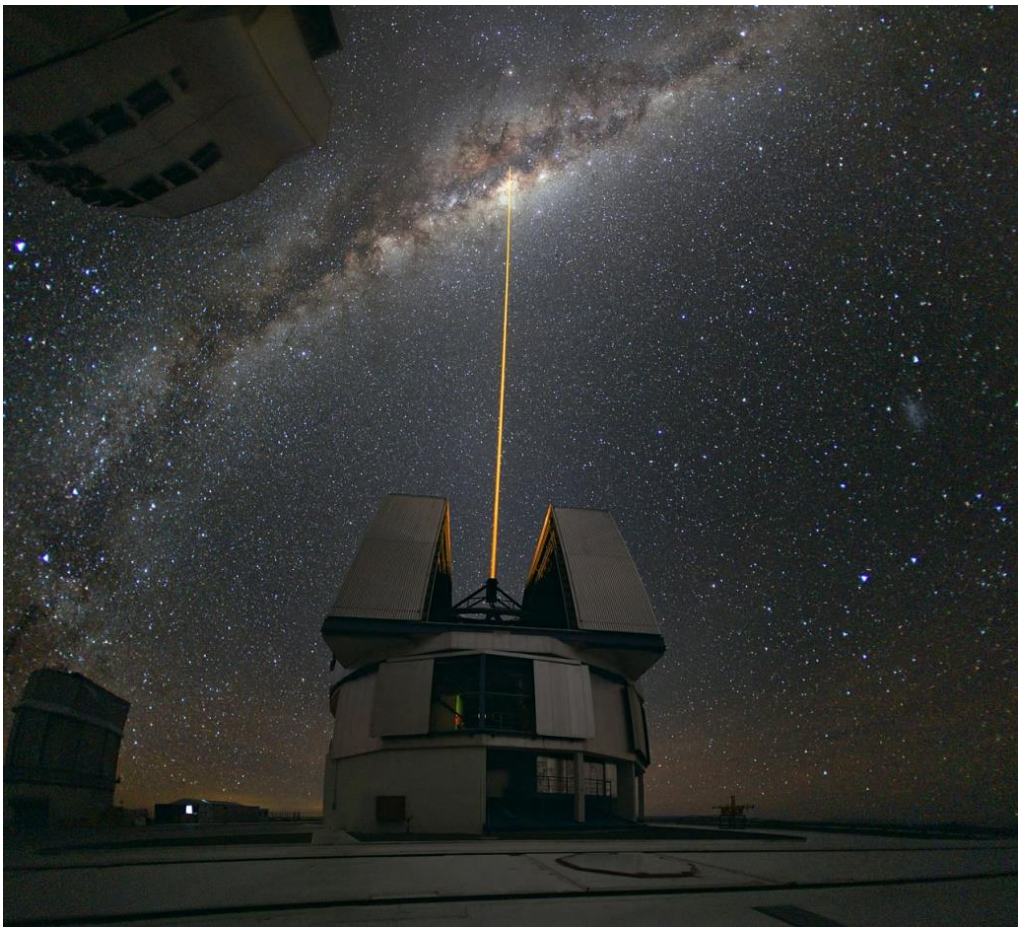
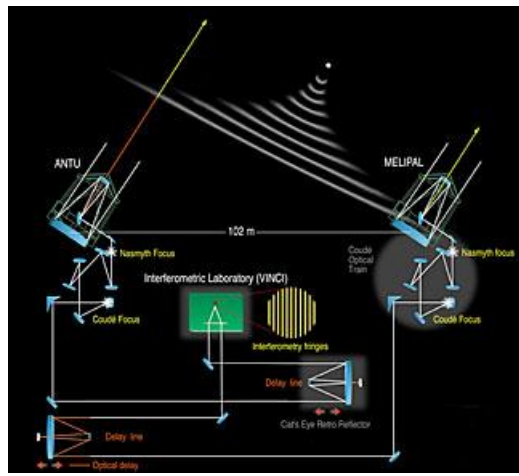
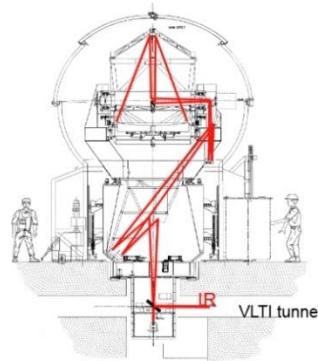


ESO Optical Components: Optical Coating

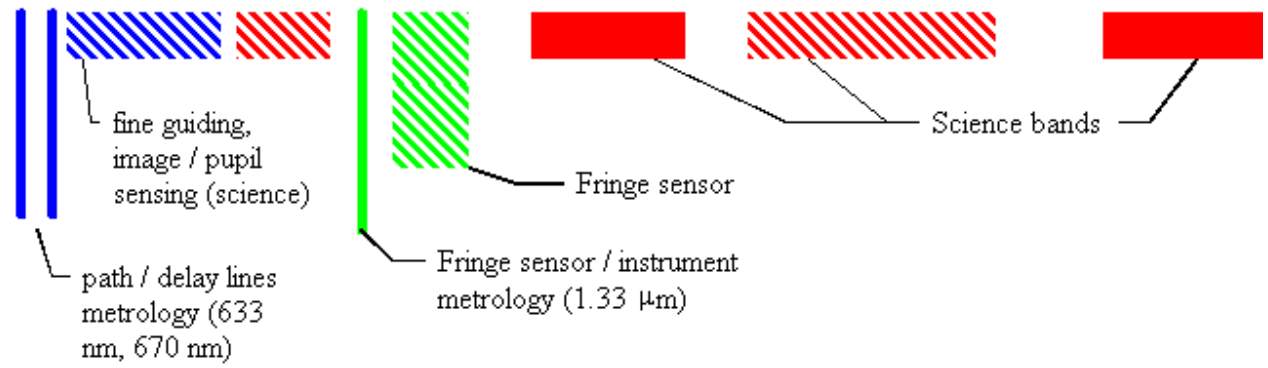
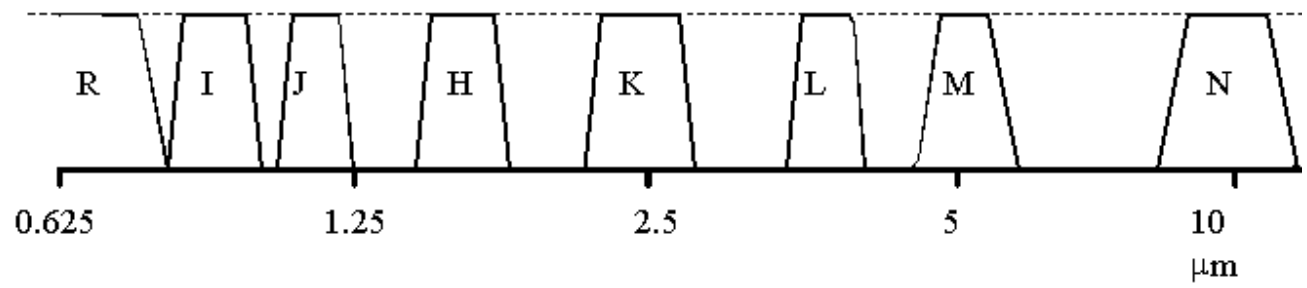
Almost all optics used in ESO projects require coatings of some form.

- For mirrors, typically a coating solution will involve an undercoat, metallic reflective coat (eg. Ag or Al), and dielectric overcoats, both for surface protection and reflectivity enhancement over a given band of wavelengths.
- For refracting components requirements can range from simple monolayer coatings to multi-layer coatings with up to ~ 100 layers, used in dichroic filters, notch filters etc.
- One development area of potential interest would be in mirror coatings that maintained high reflectivity in the telescope environment for longer periods of time than current coatings. This would be of direct benefit to E-ELT, relaxing the current segment re-coating schedule.

ESO Optical Components: Optical Coating



ESO Optical Components: Optical Coating



ESO Optical Components: Optical Metrology

ESO interest in optical metrology systems can be considered in several broad categories.

- Metrology systems for measuring form, phase and/or transmitted wavefront quality .
 - interferometers.
 - phase contrast interferometers.
 - Shack Hartmann wavefront sensors, Pyramid sensors, Curvature sensors and similar systems.
 - Deflectometry.

- Systems of use in direct surveying of optical component and interface position and alignment. E.g.:
 - metering rods.
 - alignment telescopes.
 - laser tracers, laser radar, photogrammetry.

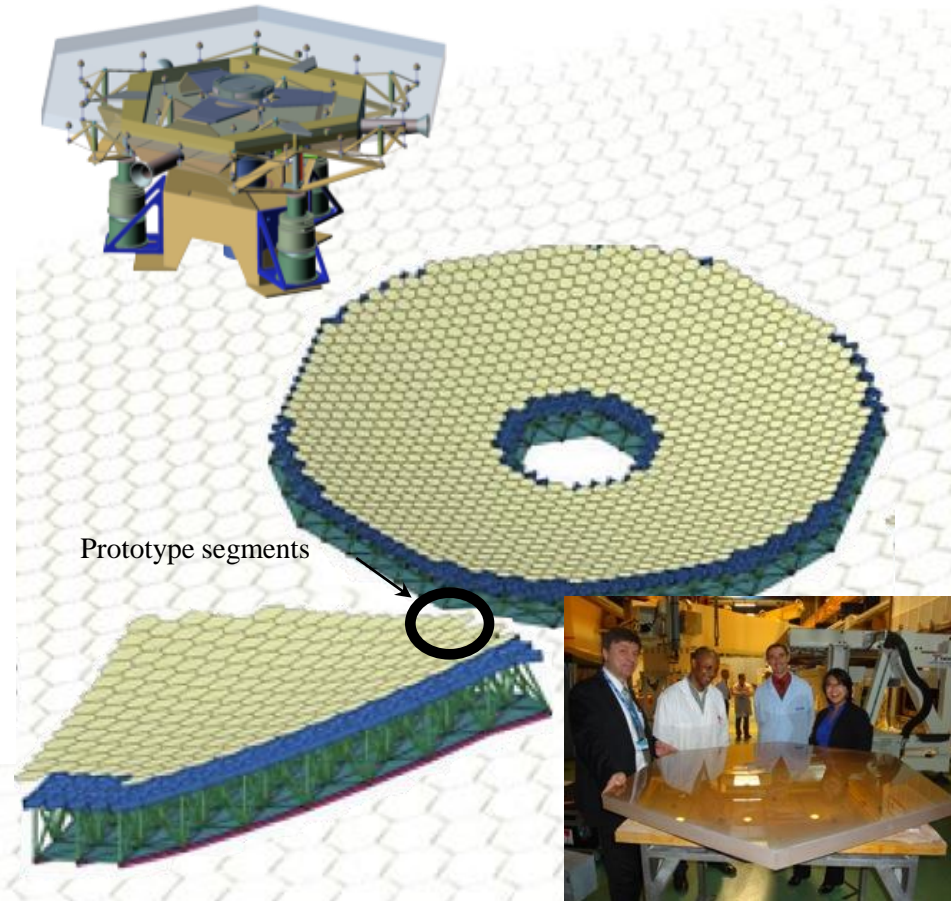
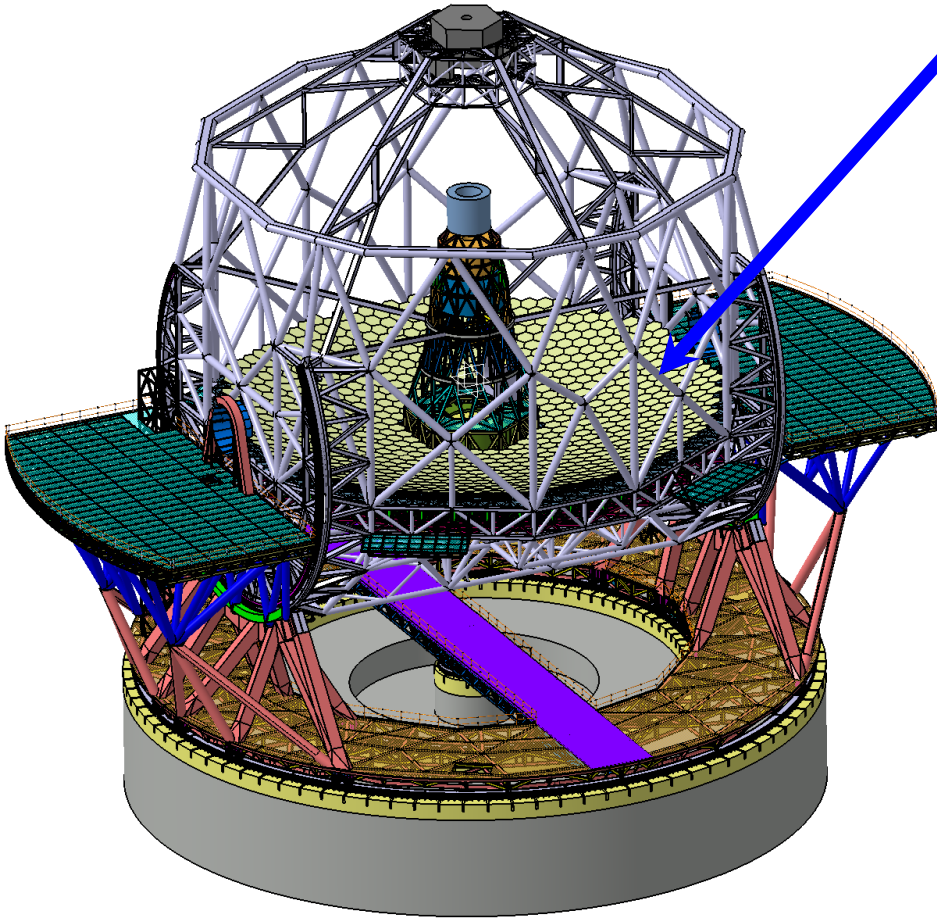
- Systems for measuring optical throughput, reflectivity , spectral response.
 - spectro-photometers
 - photometers



E-ELT Optics Support

39m Primary Mirror (M1)

- 798 mirror segments
- 27 axial support pads + 6 lateral supports + 3 clocking pads + 12 edge sensors per segment
- >38000 pads to be glued on glass mirrors

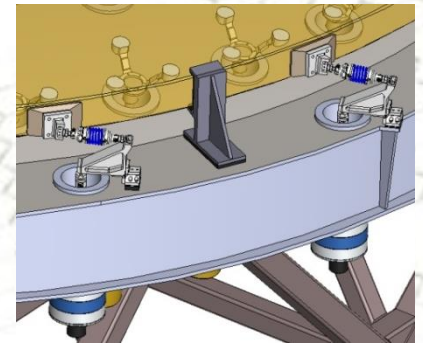
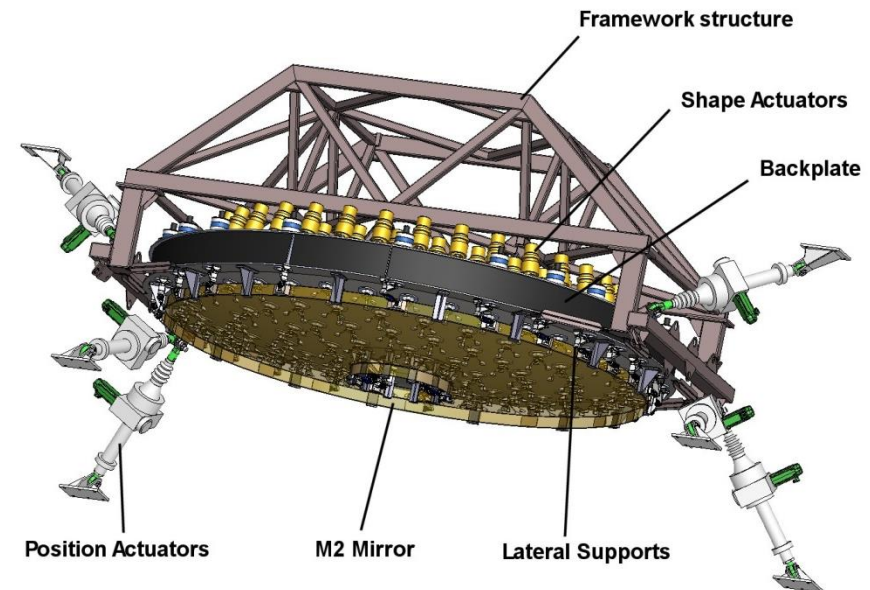
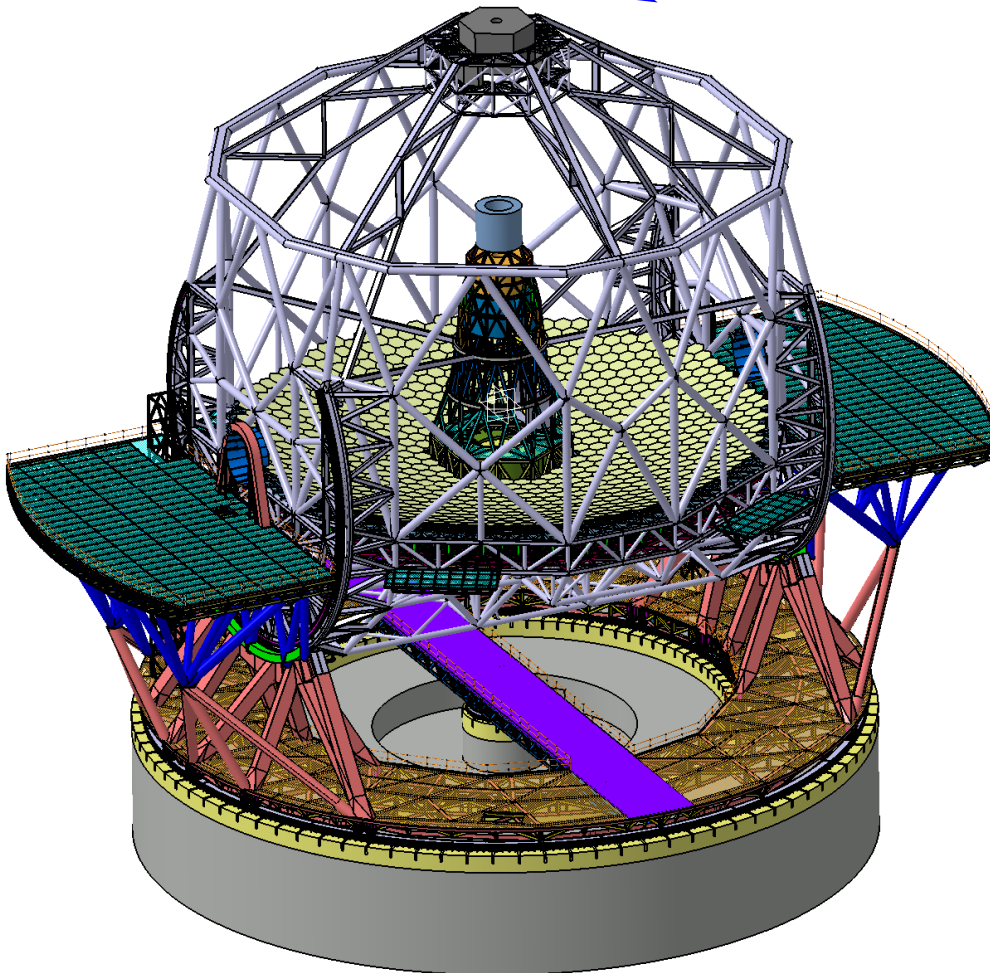
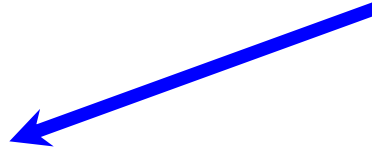




E-ELT Optics Support

4m Secondary Mirror (M2)

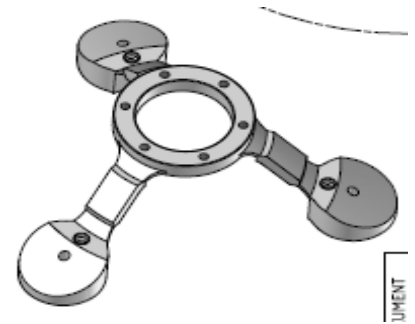
- M2 Mass 3600 kg
hanging on 54 axial support pads glued on M2



E-ELT Optics Support

Gluing axial support pads/tripods on M2 mirror

- M2: Zerodur (low CTE)
- Pads/Tripod: Aluminum (high CTE)
- Glue: RTV 566 (high CTE)
- Challenging requirements
 - Very low M2 surface deformation under $dT=15\text{ }^{\circ}\text{C}$
 - structural safety under extreme thermal and earthquake
- Average axial tensile force per pad:
 - Gravity: 150 N ($\sim 0.3\text{ MPa}$, permanent load)
 - Earthquake: 1050 N ($\sim 3\text{ MPa}$)
- Interested in alternative glue material
 - e.g. low E-Modulus, higher strength limit for temperature range between $-15\text{ }^{\circ}\text{C}$ and $85\text{ }^{\circ}\text{C}$



Thin shells for deformable mirrors



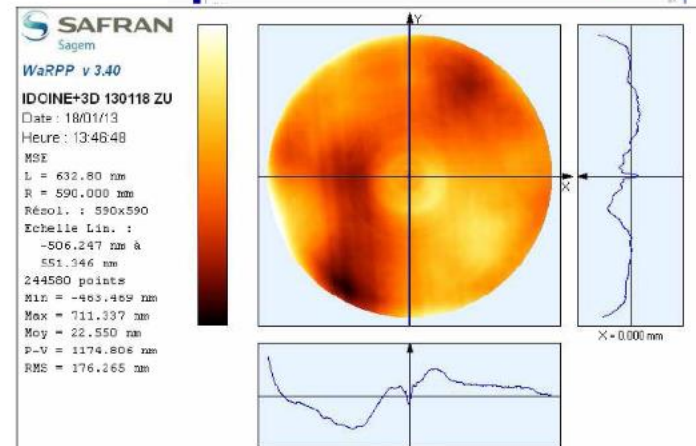
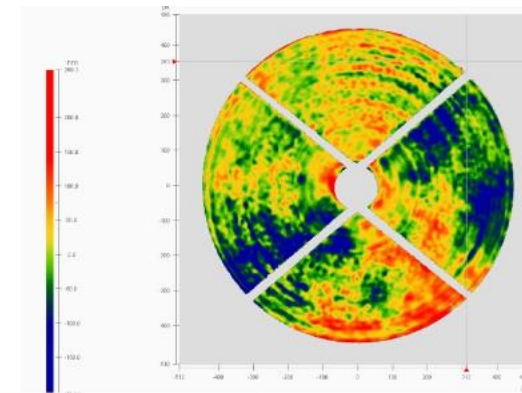
1.1m Zerodur shell
manufactured
at SAGEM



2.6m glass shell, 2 mm thick at
SAGEM

Thin shells for deformable mirrors

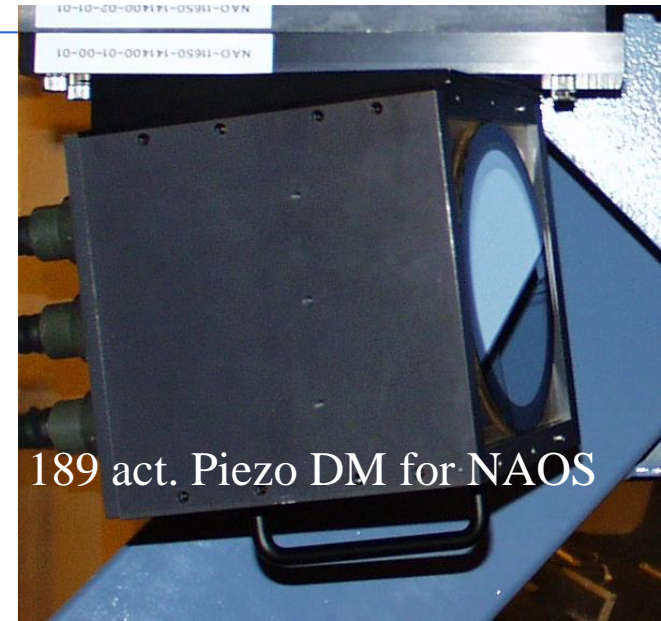
- Less 2 weeks into Optical Tests, DSM surface brought from ~ 1 mm RMS (30modes) down to 56 nm RMS surface with 600modes (to be further improved)
- The DSM Spare Shell (REOSC) convex face outstanding; 1.1 mm PV reached with ion beam figuring; fully in spec., better than 1st science shell. Thinning is starting



Piezo ceramics for deformable mirrors

Key technologies

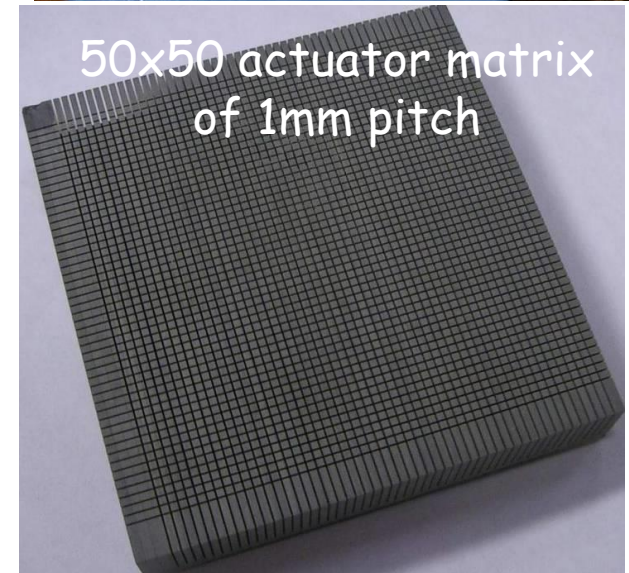
- precision slicing of ceramic blocks to make thousands of individually addressable actuators
- lithography of conductive contacts



189 act. Piezo DM for NAOS



377 act. Piezo DM for SPHERE
with its drive electronics

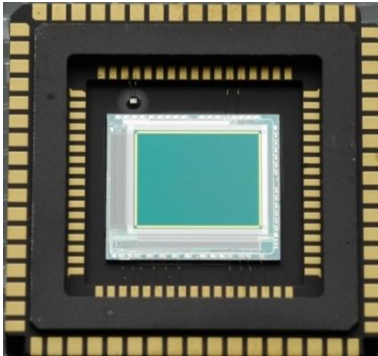


50x50 actuator matrix
of 1mm pitch

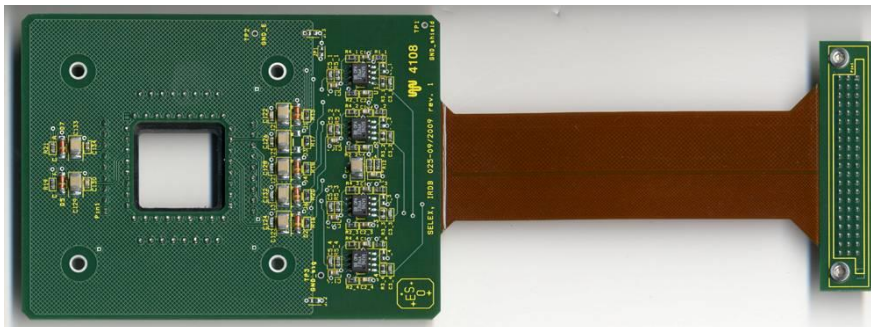
Photon detection materials

HgCdTe

- unlike silicon HgCdTe offers noiseless avalanche gain of up to 33
- Development programme ongoing with Selex UK



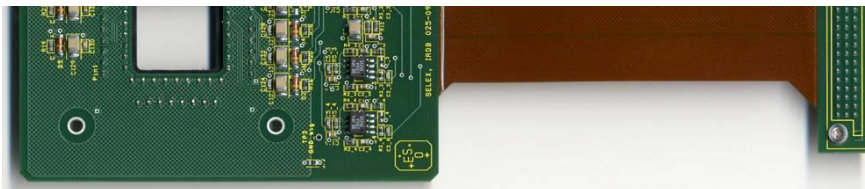
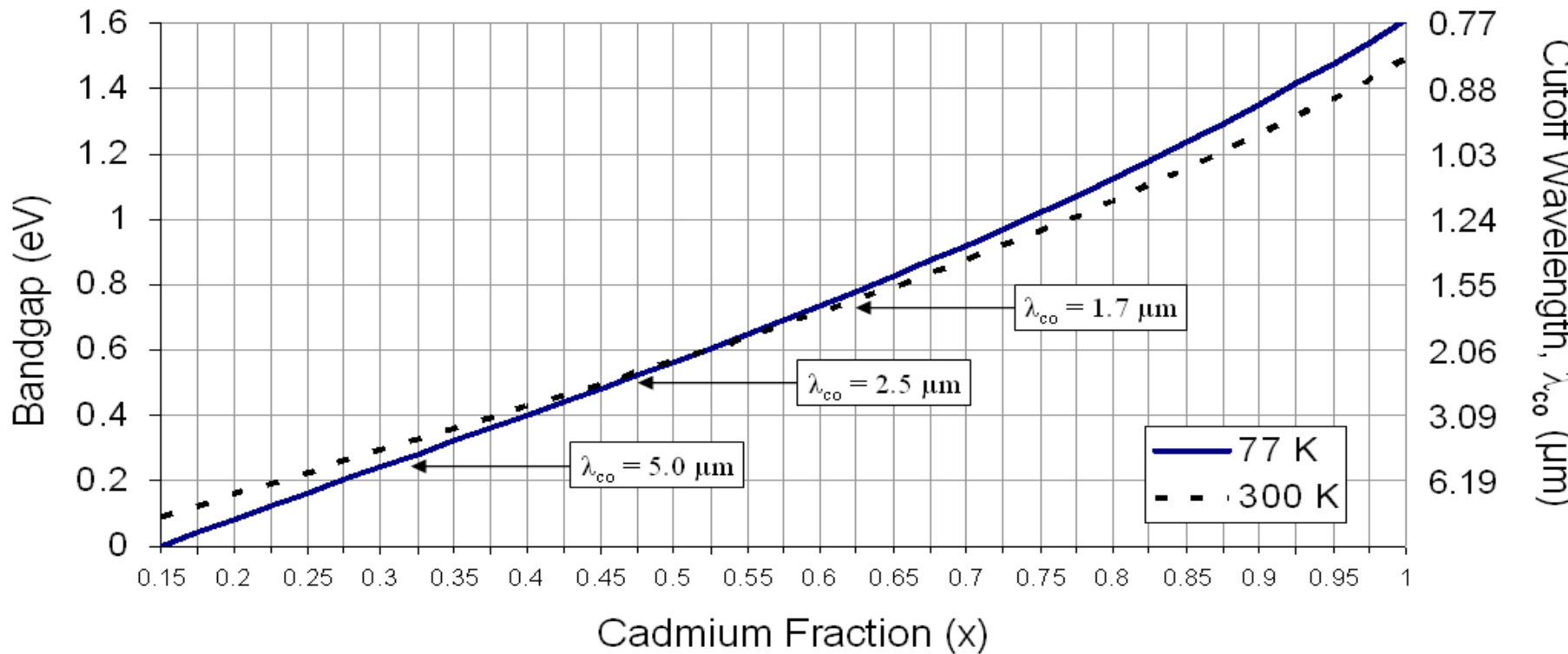
320x256 eAPD array



Photon detection materials

HgCdTe

Bandgap and Cutoff Wavelength as function of Cadmium Fraction (x)



Thank you!

