Adaptive Secondary Mirror for the European Solar Telescope: technology challenges and prototype development

Solarnet-S3
11–15 September 2023
M9 MUSEUM OF THE 20TH CENTURY
Venezia Mestre

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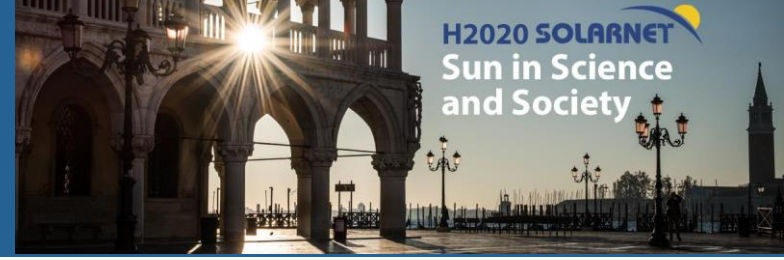
A.D.S. International

Outline

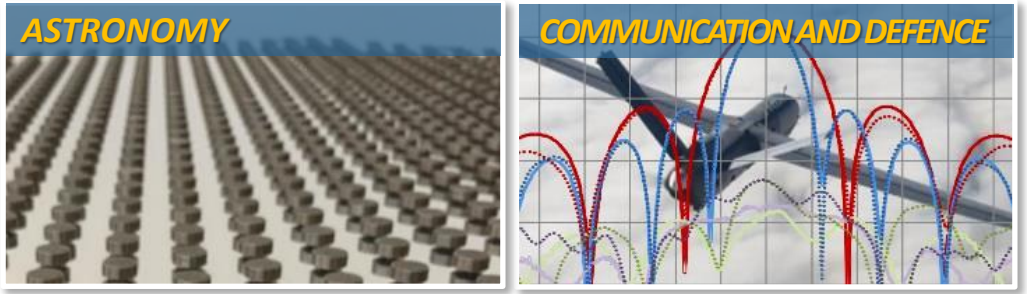
- Adaptive Secondary Deformable Mirrors for nightime astronomy (2001 – present)
- Deformable Mirrors with contactless technology: features & performances
- Daytime operation challanges
- EST-ASM: proposed design and performance analytical results
- Validation Prototype: design features and test plan

A.D.S. International (in one slide)



- Established 1997, privately owned, 22+ employees

from concept to object



- <u>In-house capability</u>:
  - Engineering + Manufacturing (mech.+elect.) + Qualification (certified labs)
  - Assembly Integration Verification
    - 1300 m^2 assembly hall 11 m high
    - clean rooms:
      - 40 m^2 and 4 m high optical lab
      - 150 m^2 and 6 m high opto-mech integration
    - 1.8 m coating chamber

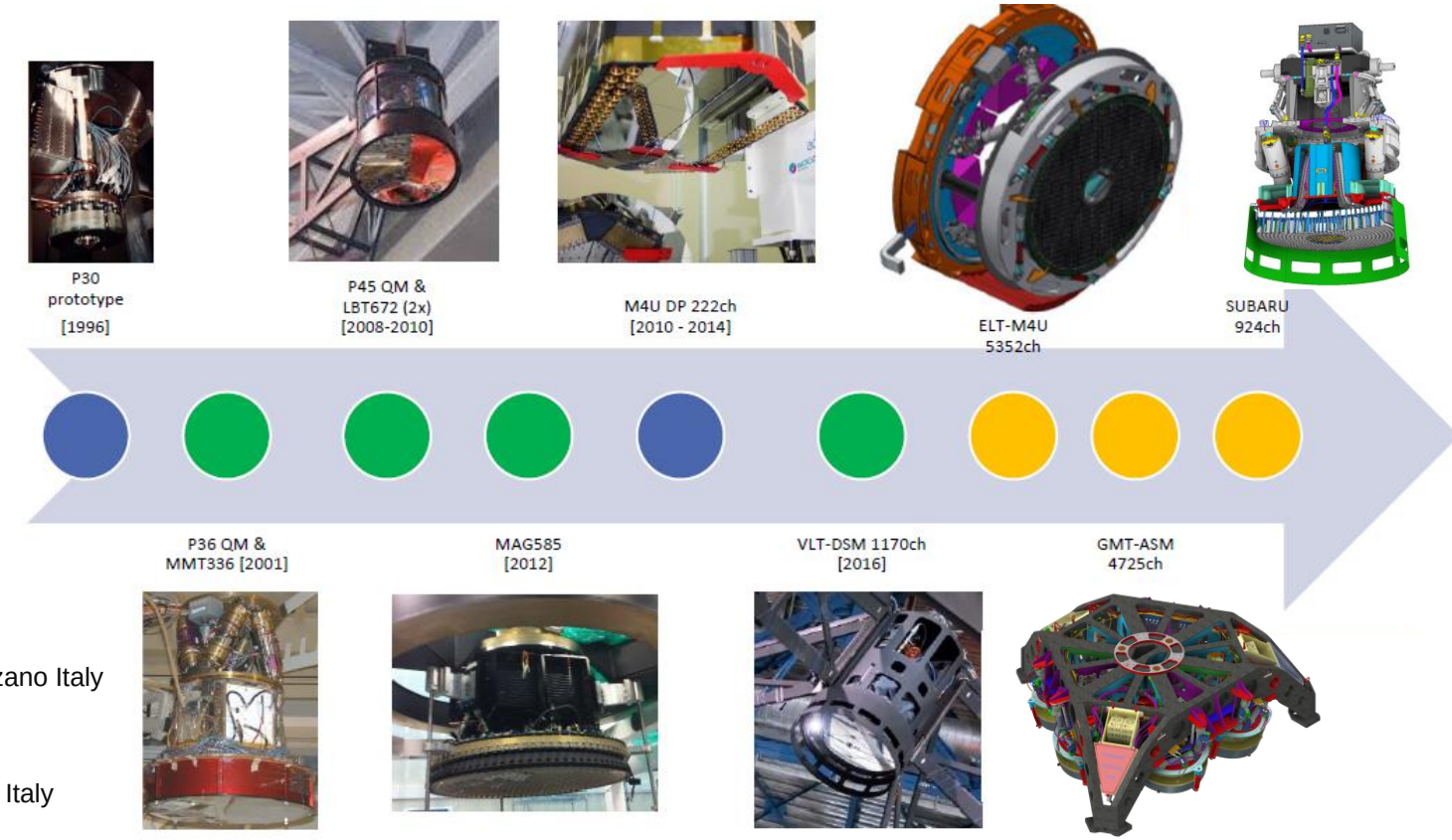
Adaptive Secondary Mirror for the European Solar Telescope: technology challenges and prototype development

Our DMs timeline

- Large Deformable Mirrors technology **developed with INAF (since 1993)**
- Deformable Mirrors embedded in large telescopes:

ADS & MICROGATE

adoptica



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P.Salinari, C. Del Vecchio and V.Biliotti

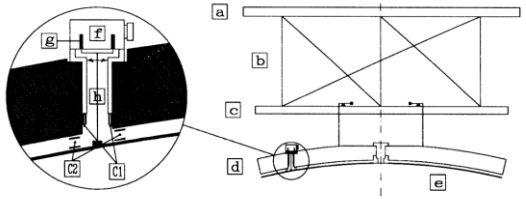
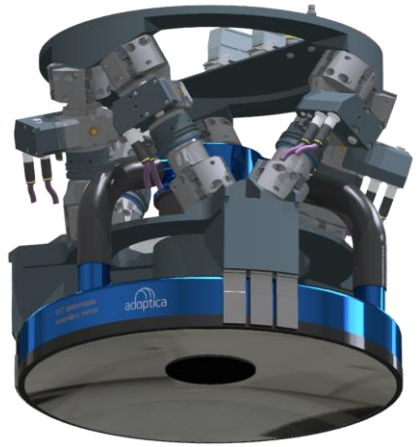


Figure 1: The conceptual Scheme of the Adaptive Secondary Unit.

EST-ASM Preliminary Design



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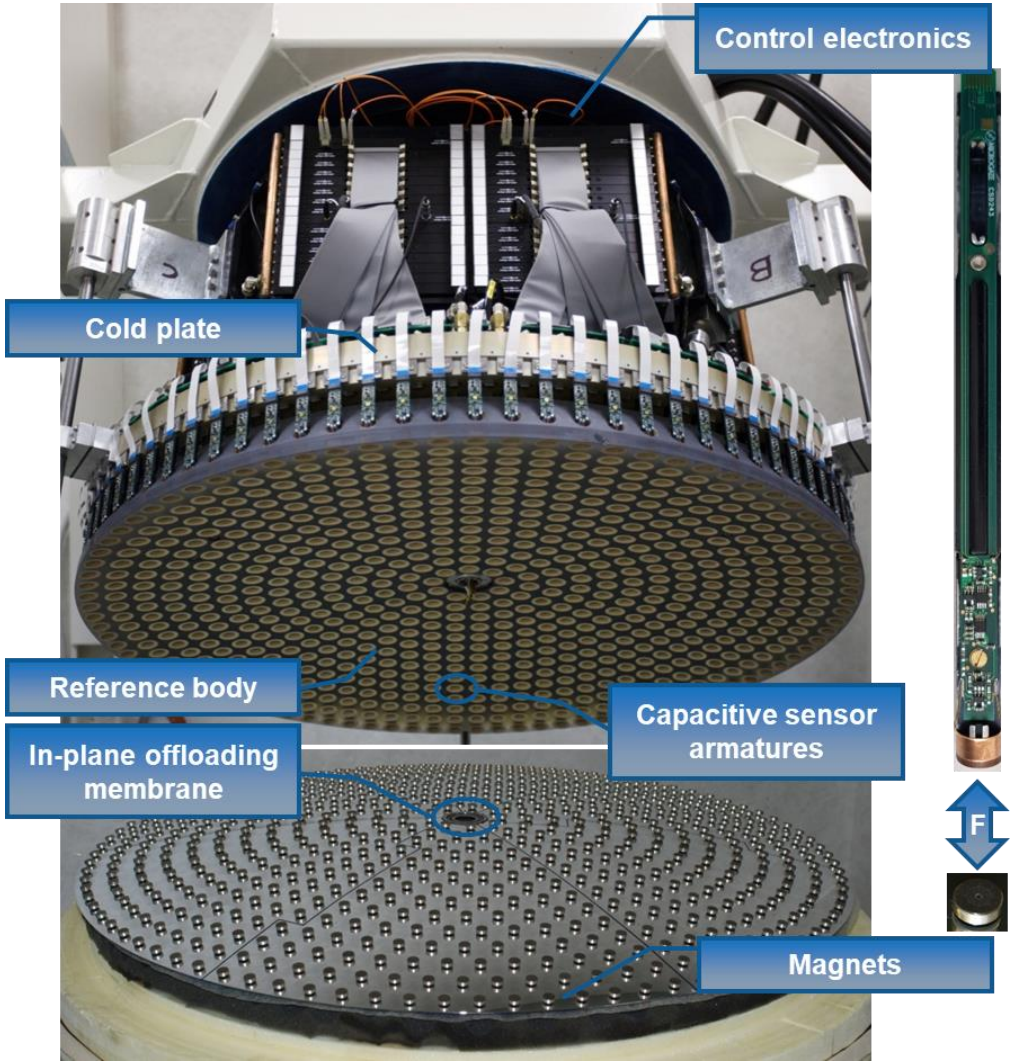
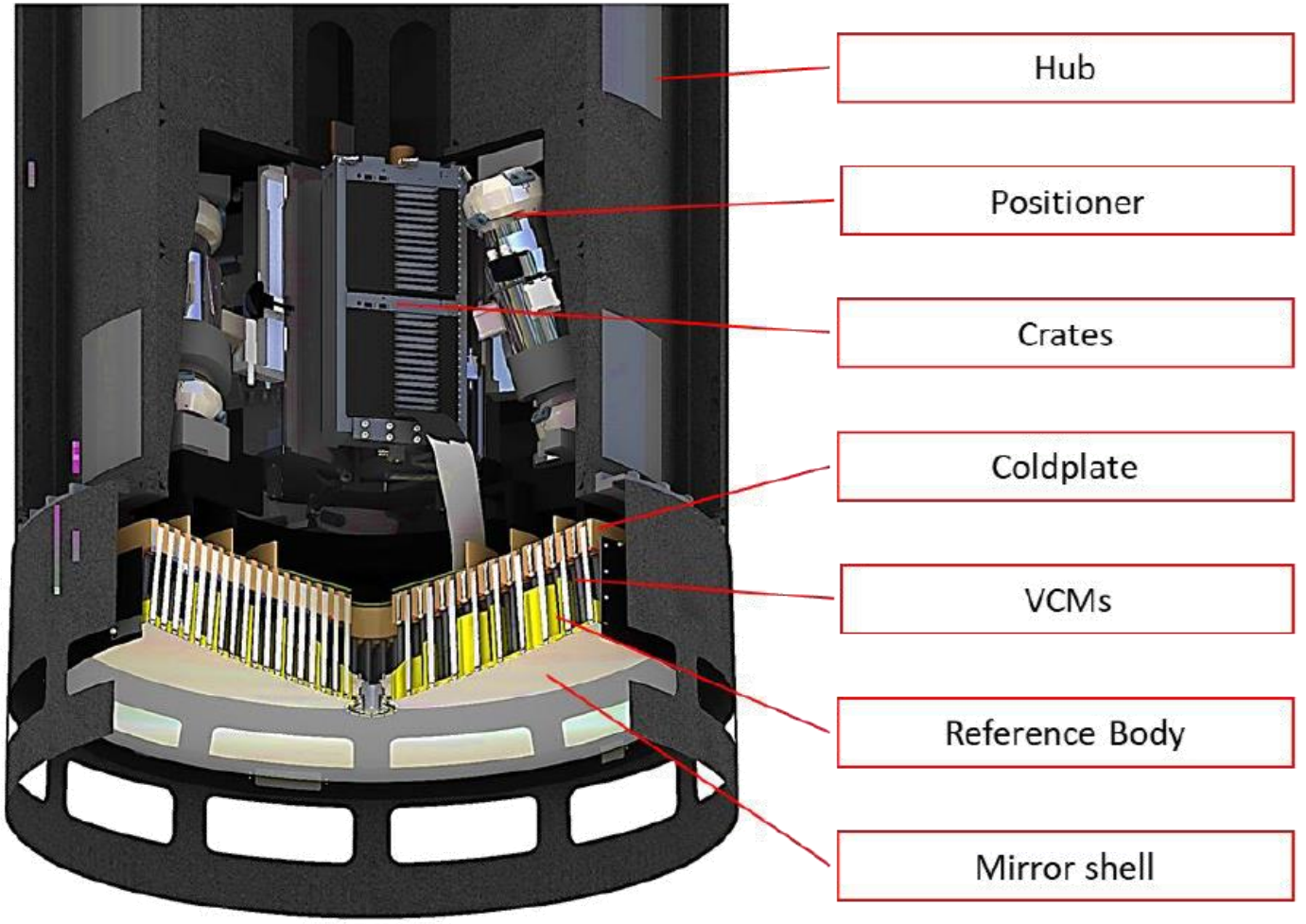
Large contactless DM features



GEN.2 - LBT



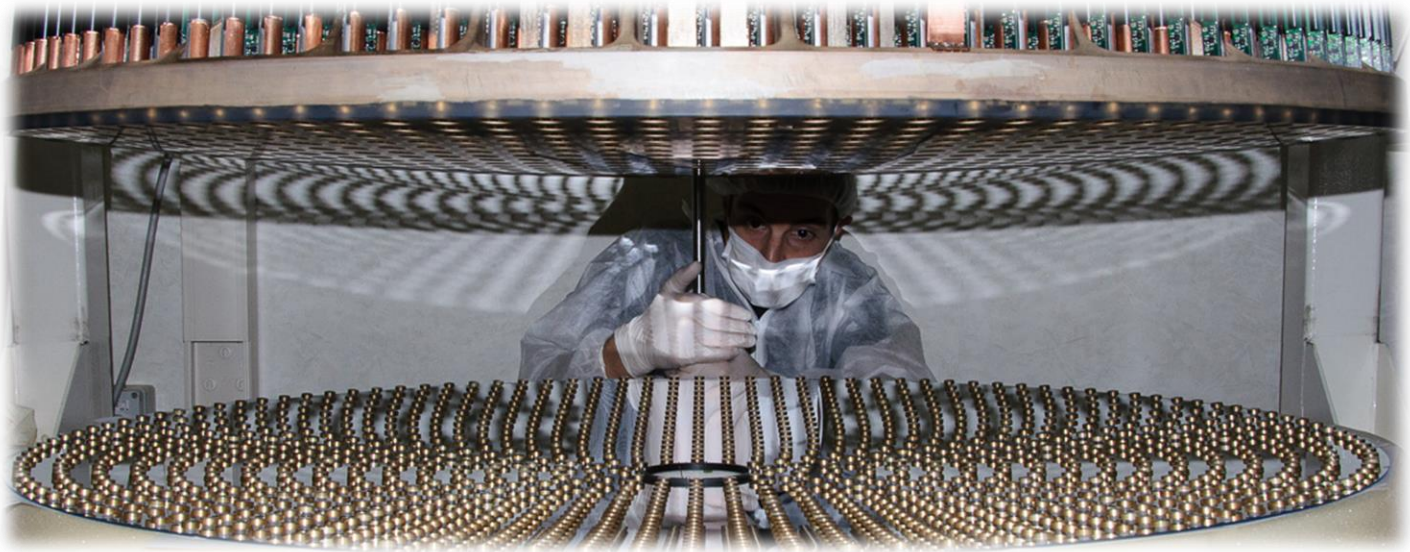
GEN.3 - VLT

Large contactless DM features

- Thin Zerodur shell [1,6÷2,0 mm] with permanent magnets glued on the back surface
- Contact-less Voice Coil Motor push/pull the shell

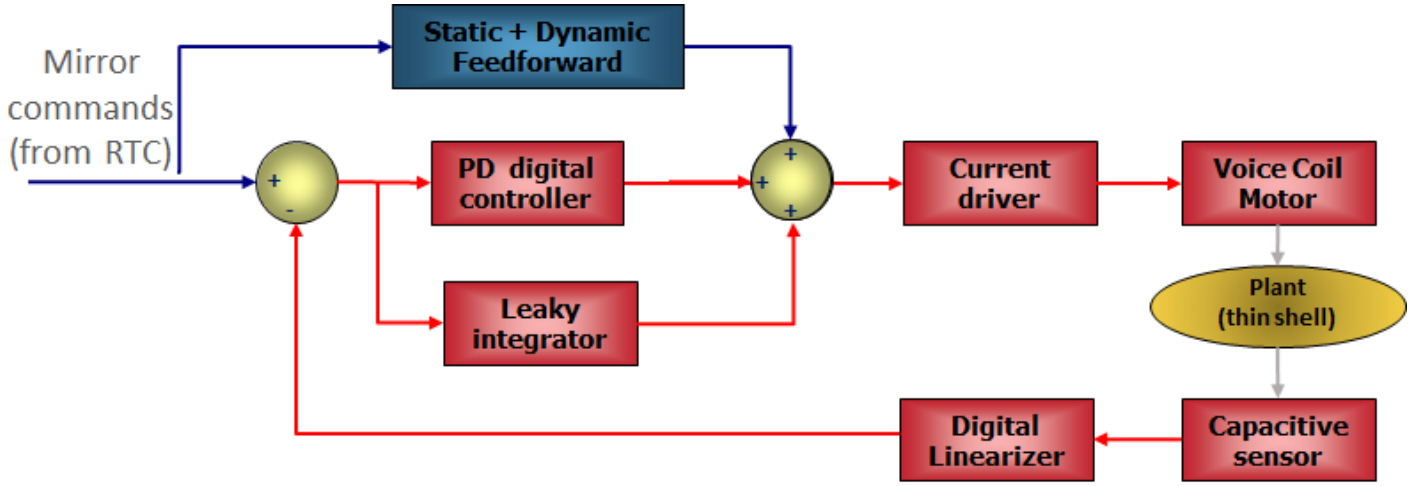
  - HYSTERESIS-FREE motion
  - FAIL SAFE, shell not constrained by dead actuator [10% acts off]

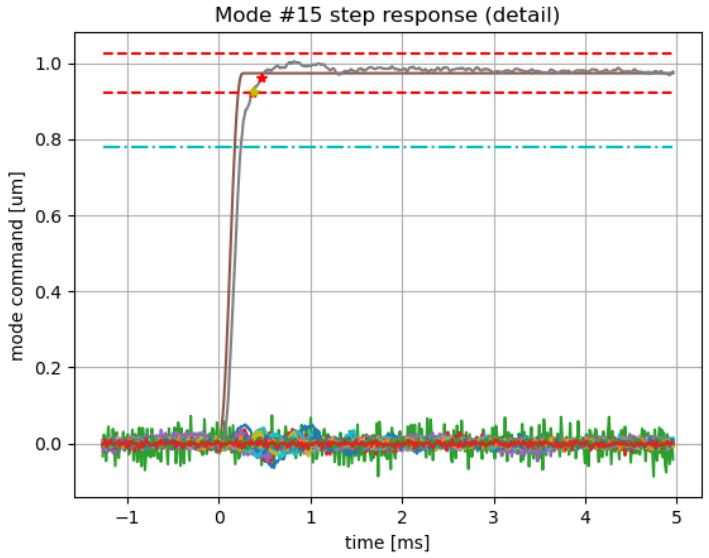
- Embedded metrology: co-located capacitive sensors read the gap between shell and Reference Body
  - Non-AO mode [1.2 nm/K drift]
- Stroke of up to 150 µm:
  - Low order aberrations
  - Field stabilization
  - High orders correction (# acts)
  - Chopping (e.g. ±20 arcsec)



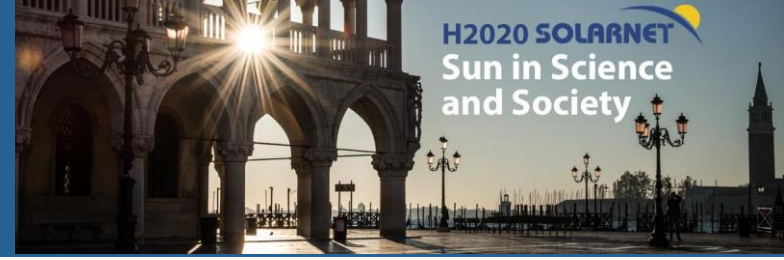
DM performances

- 0.3 ms modal step settling time, mode independent (GMT P72)
- Very limited modal crosstalk
- Short spatial scale residual: 4nm WF, shell manufact. (VLT-DSM)
- Residual shell flattening: 15-20 nm rms, incl. test opt. (VLT-DSM)

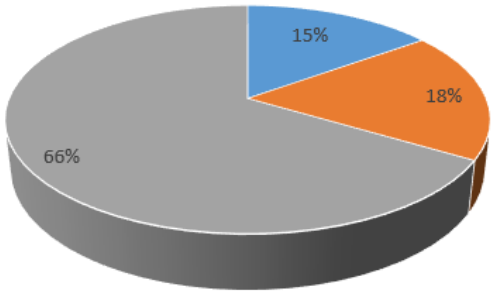




Power management

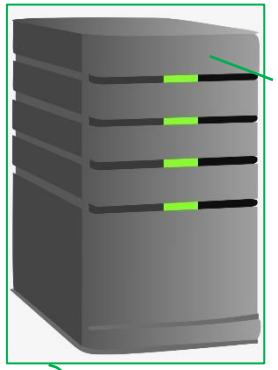


Power consumption breakdown



Coil power Driver losses Others: digital, analog, power conversion

675 acts DM	Now	Next
Coils power [W]	100	100
Other on-board power [W]	564	175
Total on-board power [W]	**664**	**275**



Workstation with FPGA accelerator and integrated NIC (MIC µXLink?).
Fast (80 kHz) control loop

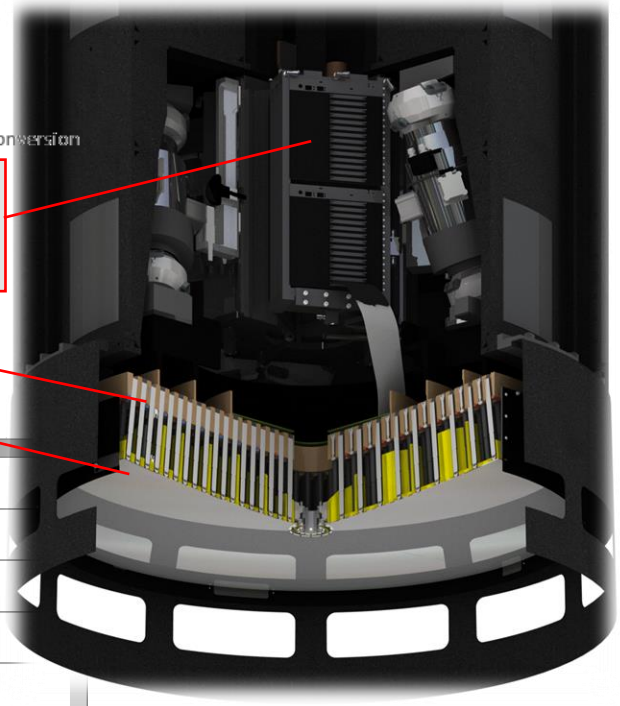
x00 m

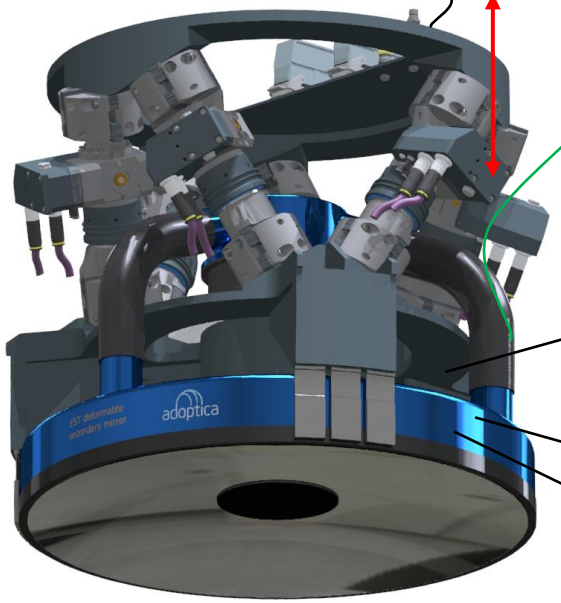
Very fast deterministic link (fiber)

Digital
Analog (fraction)
Power conv.

Analog (fraction)

Coil power

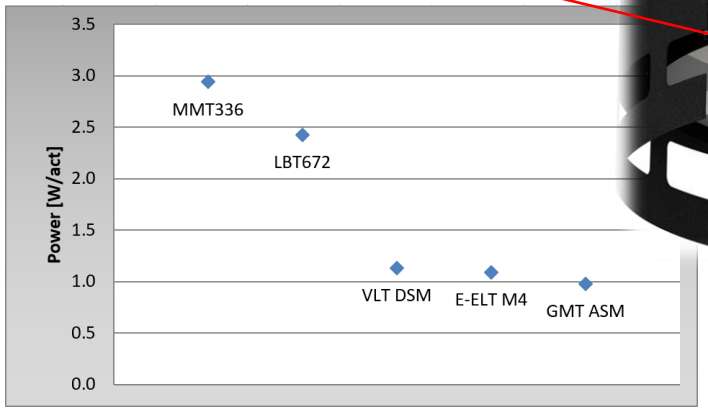




Smart distribution boards (ultra-eff coil drivers, data interface)

Analog (fraction)

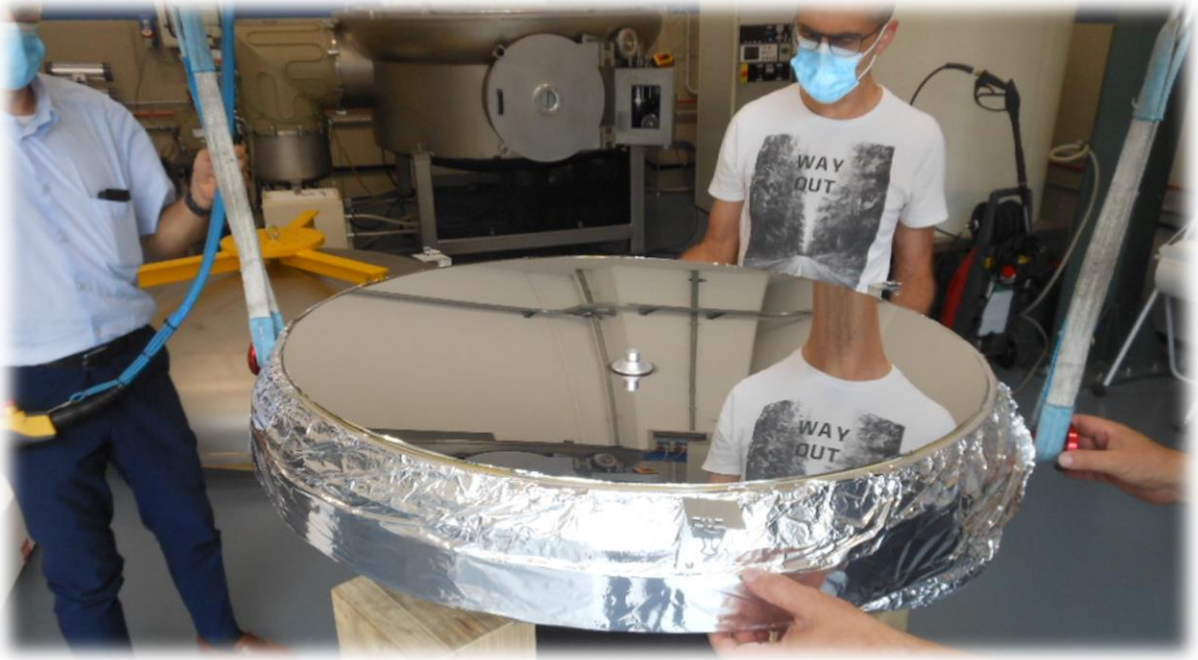
Coil power



Experience from the field

Over 20 years of field operation (MMT336 deployed in 2001)

- Cooling accidents
  - ~~glycol~~ → gas cooling system (direct expansion) = fault tolerant
- Maintainability experience
  - Shell recoating (LBT and VLT)
    - spare shell recommended to limit overhaul time
    - VLT-DSM shell never removed for 6 years
  - INSTALLATION / REMOVAL time 1 day
- Electronics revamping (LBT, Magellan and VLT)



Our DM tech for daytime operation – EST REQs

Adaptive compensation RqId: [00M2-0036] The wavefront fitting error after adaptive compensation shall be (worst case r0=5 cm) < 62 nm rms

→ act.pitch 16mm

Actuator pitch RqId: [00M2-0039] The actuator pitch shall be less or equal than 16.2mm

Mirror fast positioning OL Bandwidth (-3dB) RqId: [00M2-0033] 350 Hz for small stroke (+-15 µrad) and 20 Hz for full stroke (+-82.5 µrad)

→ Settling time [ms] ≤ 0.5 (within 10%) [capsens reduced area, noise]

Mirror fast positioning ranges RqId: [00M2-0029] Full stroke
Rx Ry ± 82.5 µrad

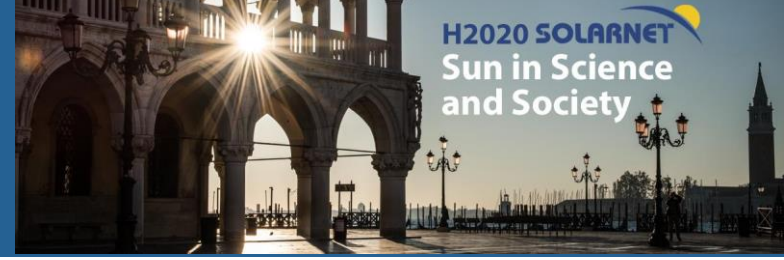
→ 100 um act.stroke, 6um AO correction, etc > **160 um act.stroke**

Mirror temperature RqId: [00M2-0052] +0.5/-1°C

Exposed surfaces temperature RqId: [00M2-0053] +1.5/-2°C

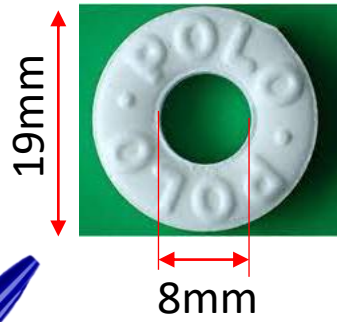
→ Power dissipation 0.35W/act + colocated electronics (direct cool) + remoted electronics

High Density Deformable Mirror: Actuators



- Actuators pitch:

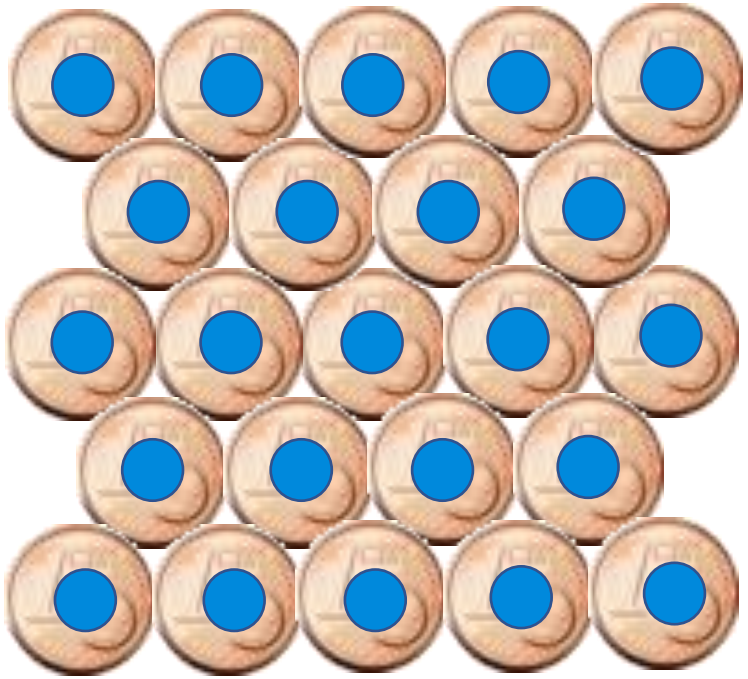
  30mm → 15-16mm



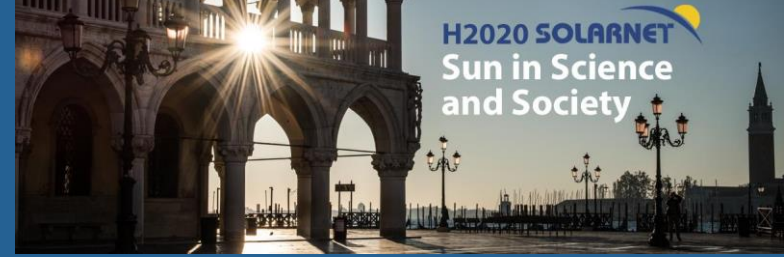
- VCM/magnet diameter:

  15-17 mm → 6-7mm

- Actuators pattern implementation:
  - each 1 € cent is a capacitive sensor area (minus mover hole)
  - inside each 1 € cent we have one VCM actuator (Bic back plug)



High Density Deformable Mirror: Capsens & Mirror



- Capacitive sensors: area, noise, …
  - area: 280 mm^2 (M4) → ~ 100 mm^2
  - → how to increase Signal/Noise?
  - → Capsens Virtualization? Clusterization?

- Mirror thickness:
  - 2mm (VLT-DSM, …) → 1.4-1.6mm (LBT shells)

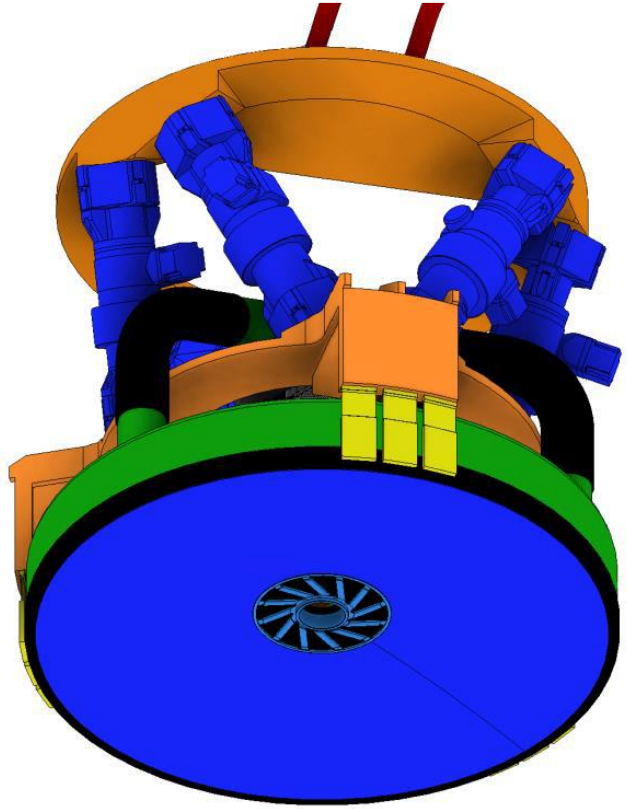
Reduce thickness to increase the inter actuator stroke and reduce the VCM forces

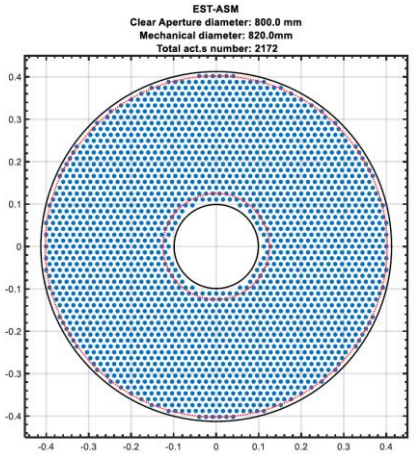
1.67 mm

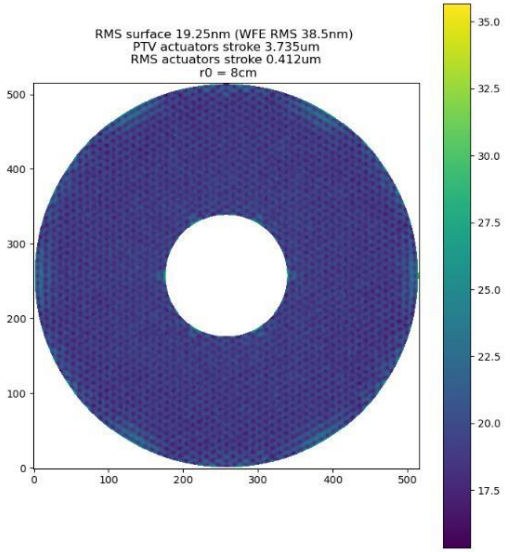
1.93 mm

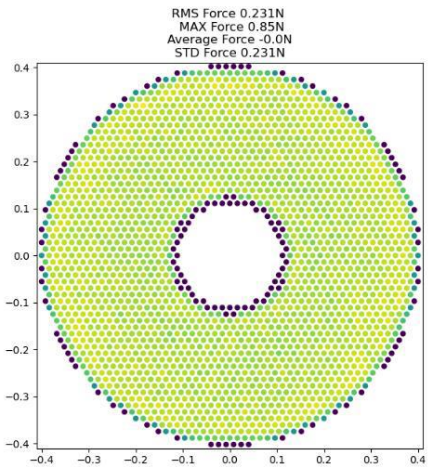
EST-ASM preliminary design

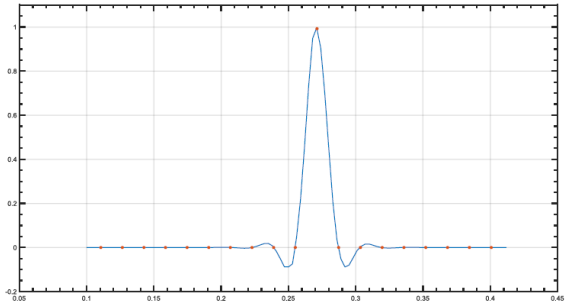
- 16mm actuators pitch → 2172 actuators over 820mm mirror
- 2040 modes available for active shape correction
- SiC Reference Body
- 0.4÷0.5 W/act
- Remoted PSU and FPGA control
- 2 kHz command tracking bandwidth
- 0.3 ms settling time







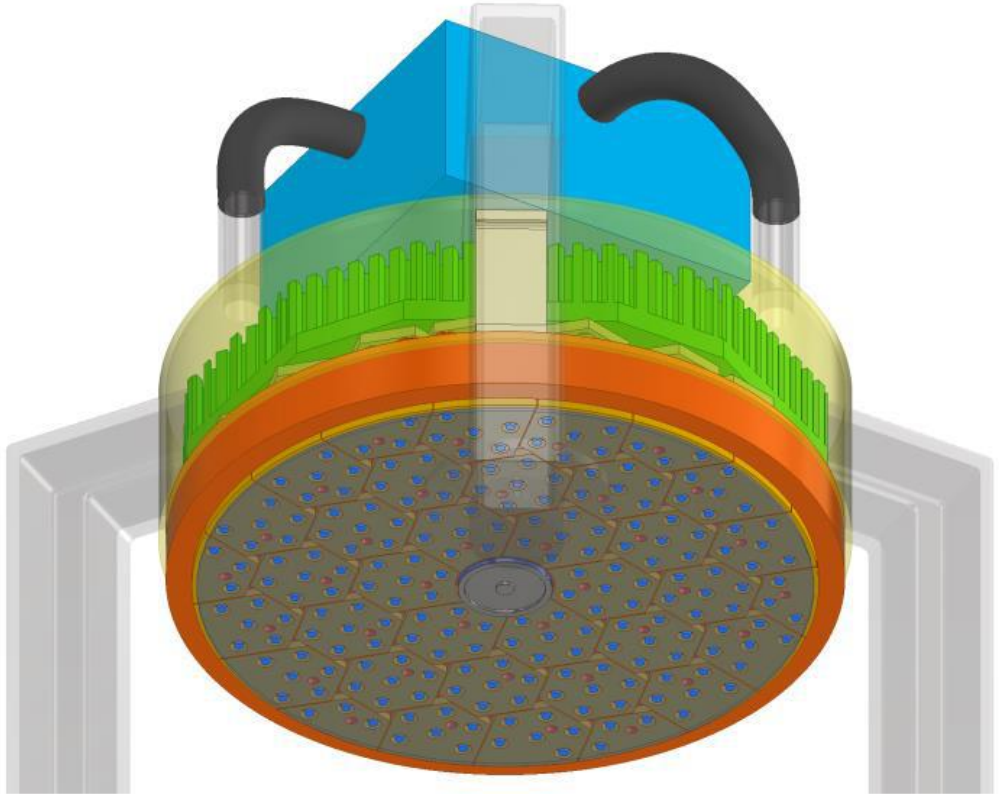




EST-ASM validation prototype

- 16mm actuators pitch → 216 actuators over 260mm mirror
- 0.4÷0.5 W/act
- 2 kHz command tracking bandwidth
- 0.3 ms settling time (@10% of step amplitude)

- Validation of:
  - Dynamic response
    (feedback noise limited)
  - Thermal management



… we'll learn it soon: 2024 (!)

Take away

- Large Deformable Mirror with contactless VCM actuators: technology suited for daytime AO
- High Density design and prototyping is in progress → EST-Adaptive Secondary
- Daytime applications: Optical Ground Stations

Proved Ingredients
New Recipe