Adaptive Secondary Mirrors

Gustavo Rahmer for the IQ Group:

Julian C. Christou, Guido Brusa, Juan Carlos Guerra, Michael Lefebvre, Douglas Miller, Richard Sosa

Large Binocular Telescope Observatory

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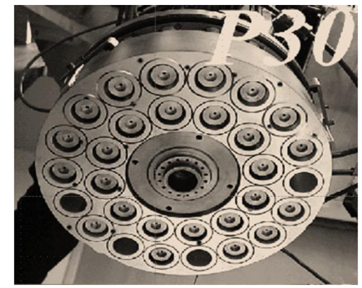
Introduction

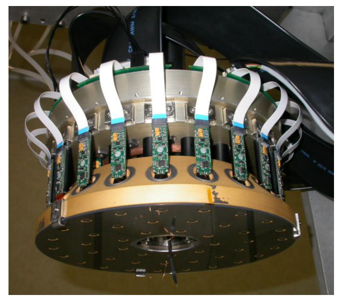
- Why use an ASM?
  - Fewer optical surfaces
    - Reduced NIR/MIR Thermal emission
  - Wider field–of-view
    - Better suited for GLAO
  - Large format permits high actuator density
    - Improved wavefront control
  - Operational with missing actuators
    - Voice coil actuators

A Brief History of ASMs

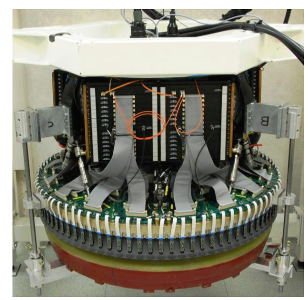
- Concept proposed by P. Salinari in 1993
  - “A study of an Adaptive Secondary Mirror”
- First prototype (30 actuators) in 1997
  - Microgate and ADS



- First unit on-sky
  - MMT336 (2000)



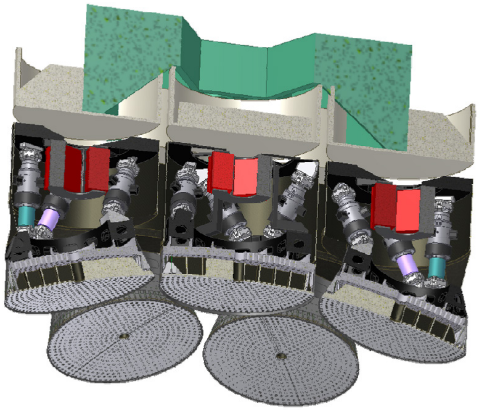
- Second Generation
  - LBT672a/b
  - Magellan MagAO



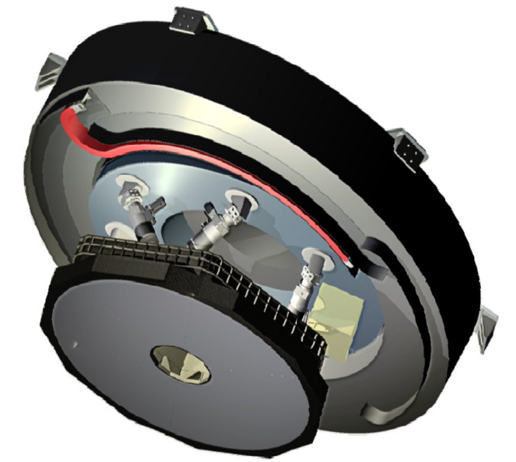
- Third Generation
  - ESO VLT UT4 Adaptive Optics Facility
  - 1170 Actuators

The Future of ASMs

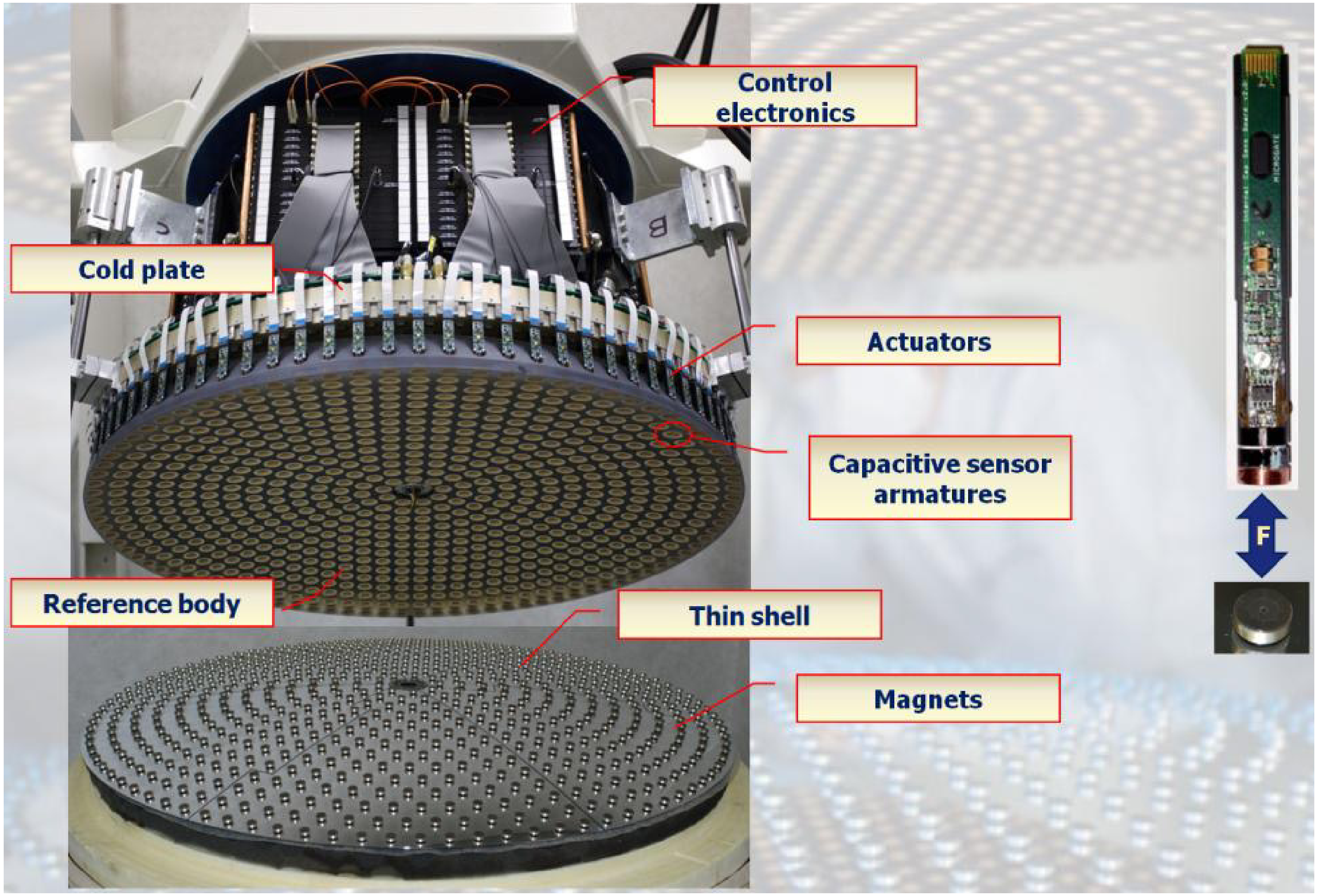
- GMT
  - Seven secondary mirrors conjugated to the primary mirrors.
  - Thin shells: 1.06 m diameter and 2 mm thick.
  - 672 actuators.



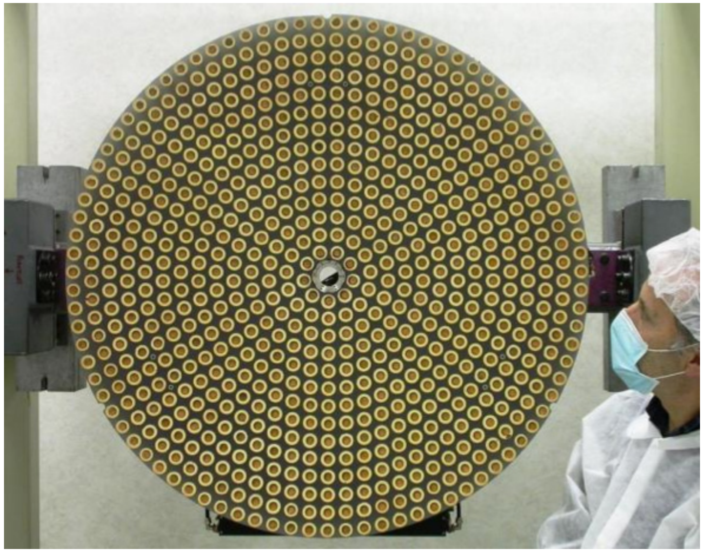
- E-ELT M4 (not really ASM)
  - 2.6x2.5 m elliptic flat mirror.
  - 6348 actuators.



Main Components



LBT672 “Key” Components



Front view of the reference body showing the actuators and the capacitive sensor armatures.

Reference body (top) and thin shell (bottom) showing the magnets on the rear of the shell.

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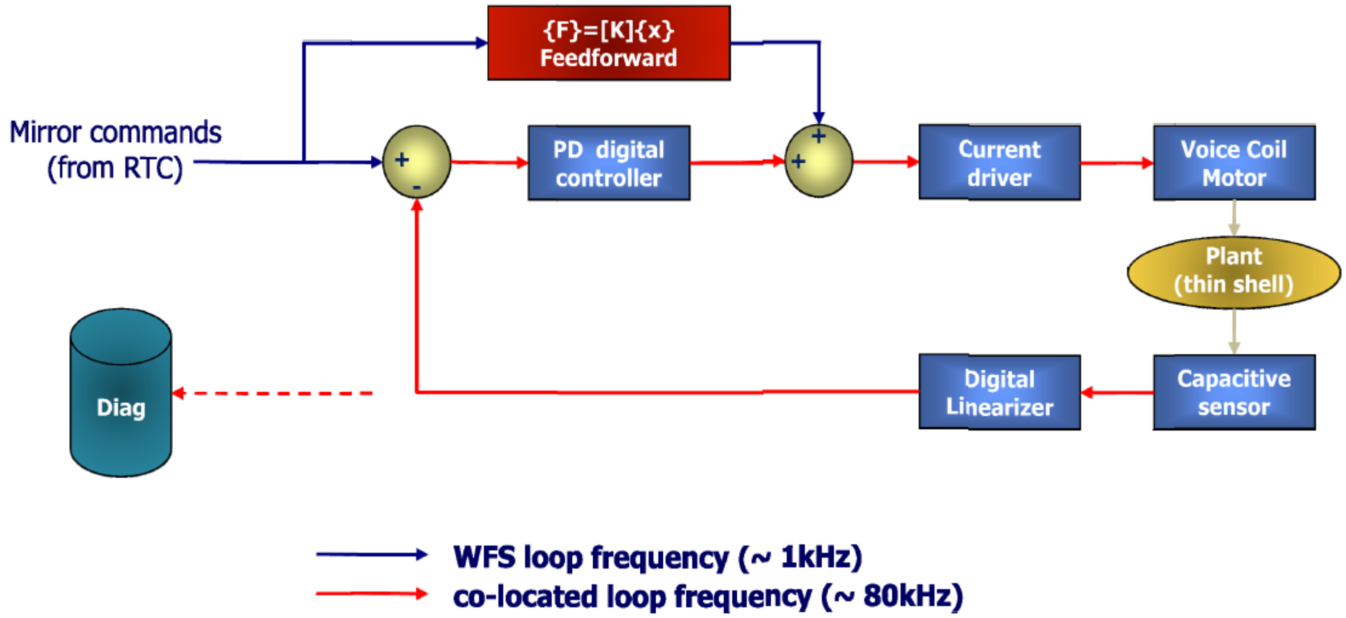
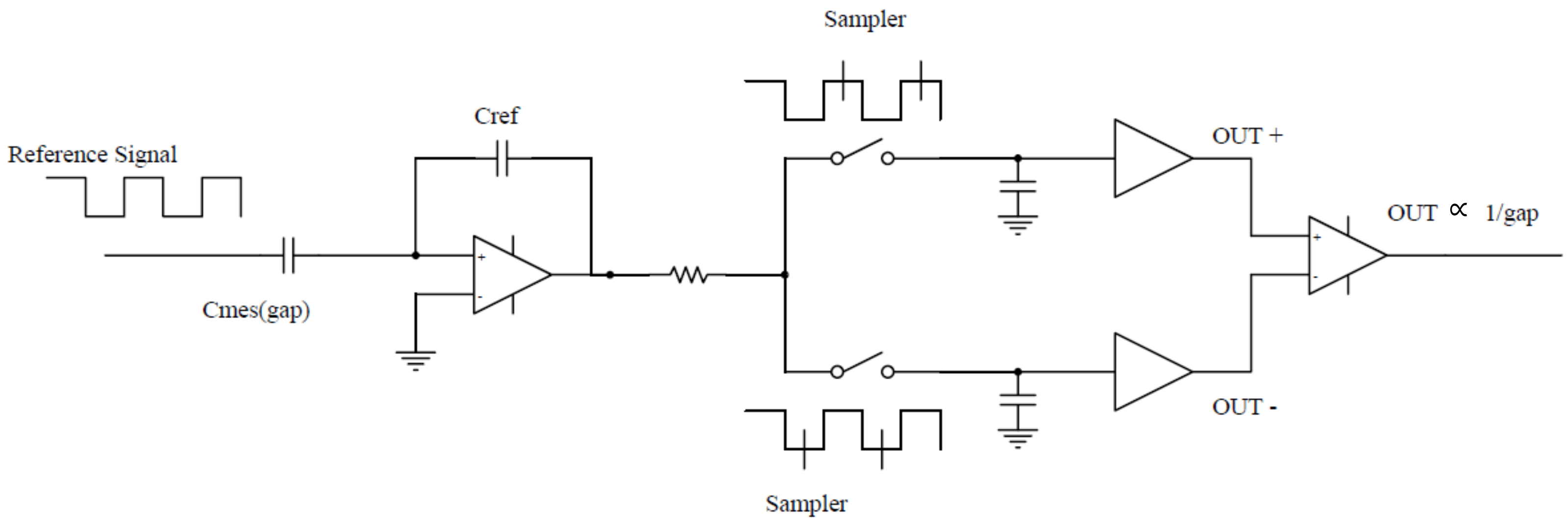
Control Loop



- Position command for each actuator is sent by the Real Time Reconstructor.
- Command is compared with capacitive sensor reading.
- Error is fed into a proportional controller.
- Additional velocity loop ptrovides damping required to mitigate the effect of high frequency modes.
- Global feed-forward is used to increase dynamic response.

Ref: “**Contactless thin adaptive mirror technology: past, present and future” (Biasi et al, SPIE 2010)**

Capacitive Sensing



- A square wave (reference signal) is injected into the capacitor formed by the Ref Body and the Thin Shell, and compared with a reference capacitance (*Cref).*
- Parallel sampling is fed to a differential amplifier.
- The result is inversely proportional to the gap.

Adaptive Secondary Operational Issues

- Facility Requirements:
  - Cooling (Electronics)
  - Power (Electronics)
  - Communication
    - Multiple WFS feed slope information to ASM
      - Fibers & BCUs

- Environmental Factors:
  - Temperature, humidity, wind
  - Gap Contamination
    - Dust particles
    - Moth “debris”
  - Shell Cleanliness
    - “Metallic dust” on secondary surface
    - Other surface contamination, oil, dust (moth & particulate), etc.

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Adaptive Secondary Operational Issues

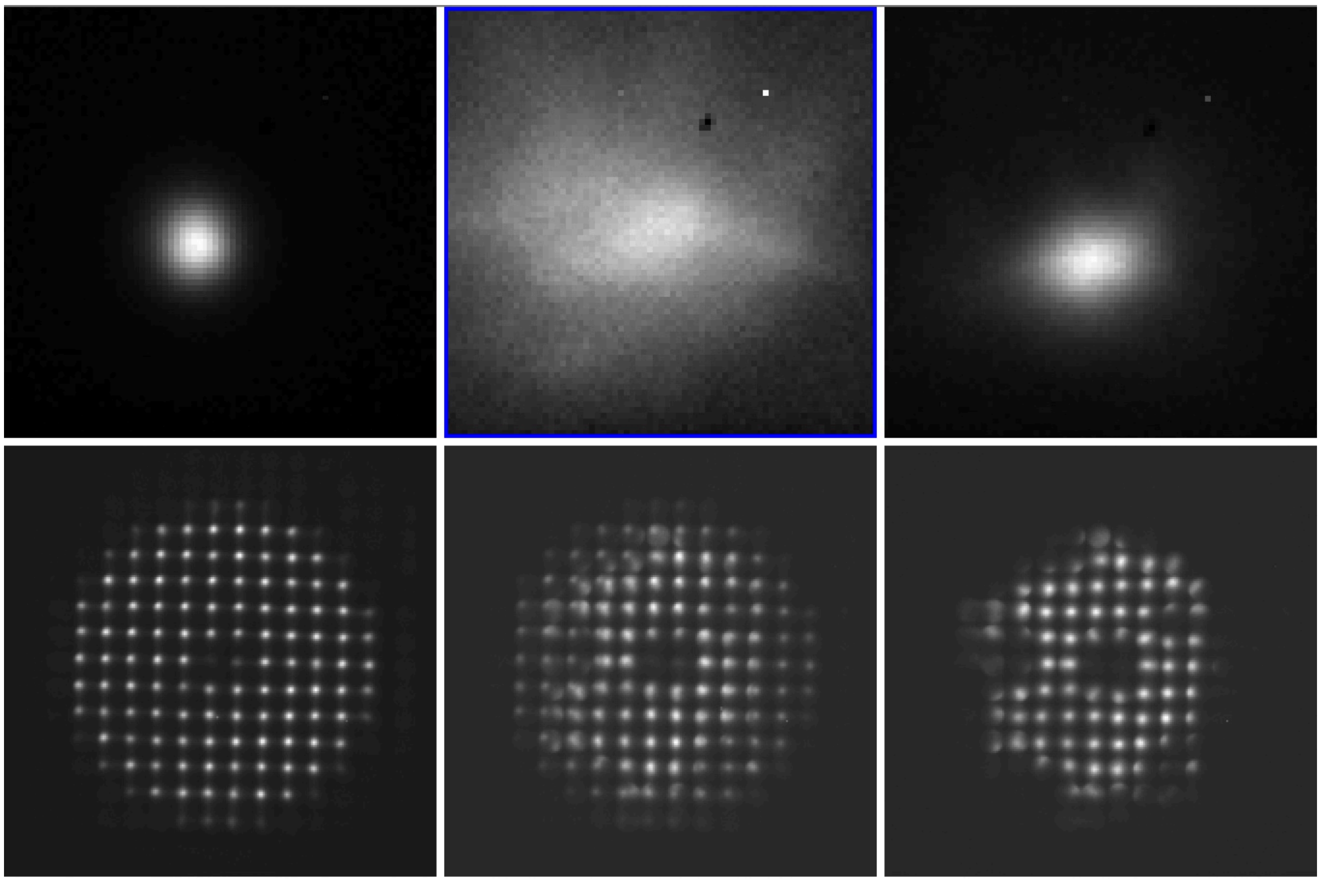
- Operational Modes:
  - ASMs are always:
    - mounted (unlike MMT & Magellan)
    - powered-on in “rest” mode
      - The thin shell is pulled against the reference body (safest state)
      - Continuous “housekeeping” monitoring (e.g. TSS)
  - Two Operational Modes:
    - Seeing-limited
      - Maintain “flat” surface (shell is “set”)
        - » Equivalent to a fixed secondary
      - Active optics on M1
    - AO/Diffraction-limited
      - Adaptive correction of shell (< 1KHz)
      - WFS slopes selected from
        - » FLAO
        - » LBTI
        - » ARGOS
        - » LINC-Nirvana

Adaptive Secondary Failure Modes

- Operational Fault Modes
  - Skip Frame
    - Secondary correction was not applied – outside ASM range
    - After N skip frames, the shell rests.
  - Actuator position or current jump
    - Shell rests & automatically software recovery
  - Software Control Problems
    - Control Process hangs
      - (IDL, Arbitrator, Inter-process Communication Manager)
    - Fastdiagnostic process dies
  - Communication problem
    - Between Control Software & ASM (Fastlink protocol)
  - Gap contamination
  - Electronics problem
    - DSP or Distribution Board Failure
  - External event
    - Overheating
    - Overcooling

Adaptive Secondary Failure Modes

- An ASM failure causes:
  - The shell to "*RIP*" into a rest state.



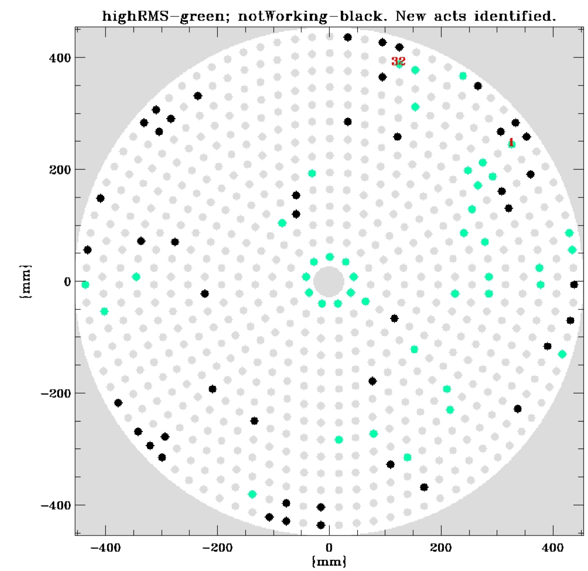
The guider FWHM before the RIP was 1.1", after the RIP was 1.7"

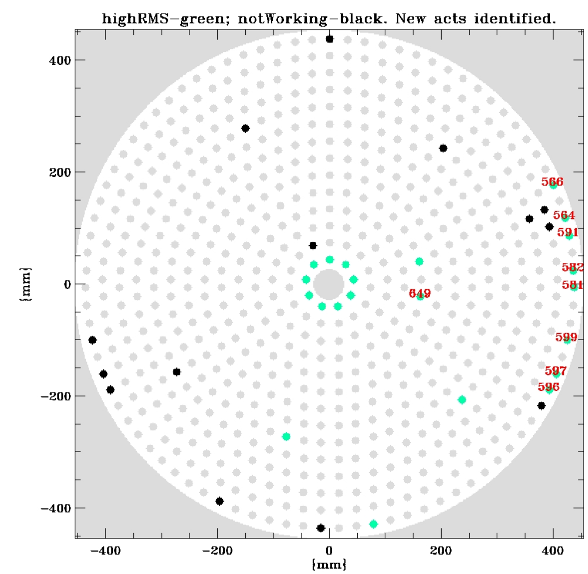
Adaptive Secondary Failure Modes

- Actuator Malfunction
  - Detached magnets
  - Dirty contacts
  - Electronics failure
    - Capacitive sensor
  - Voice-coil failure

Note: when ~10% of actuators are removed then performance can be compromised, especially when they are clustered.

black: actuators with non-working capacitive sensor
green: actuators with high RMS position reading





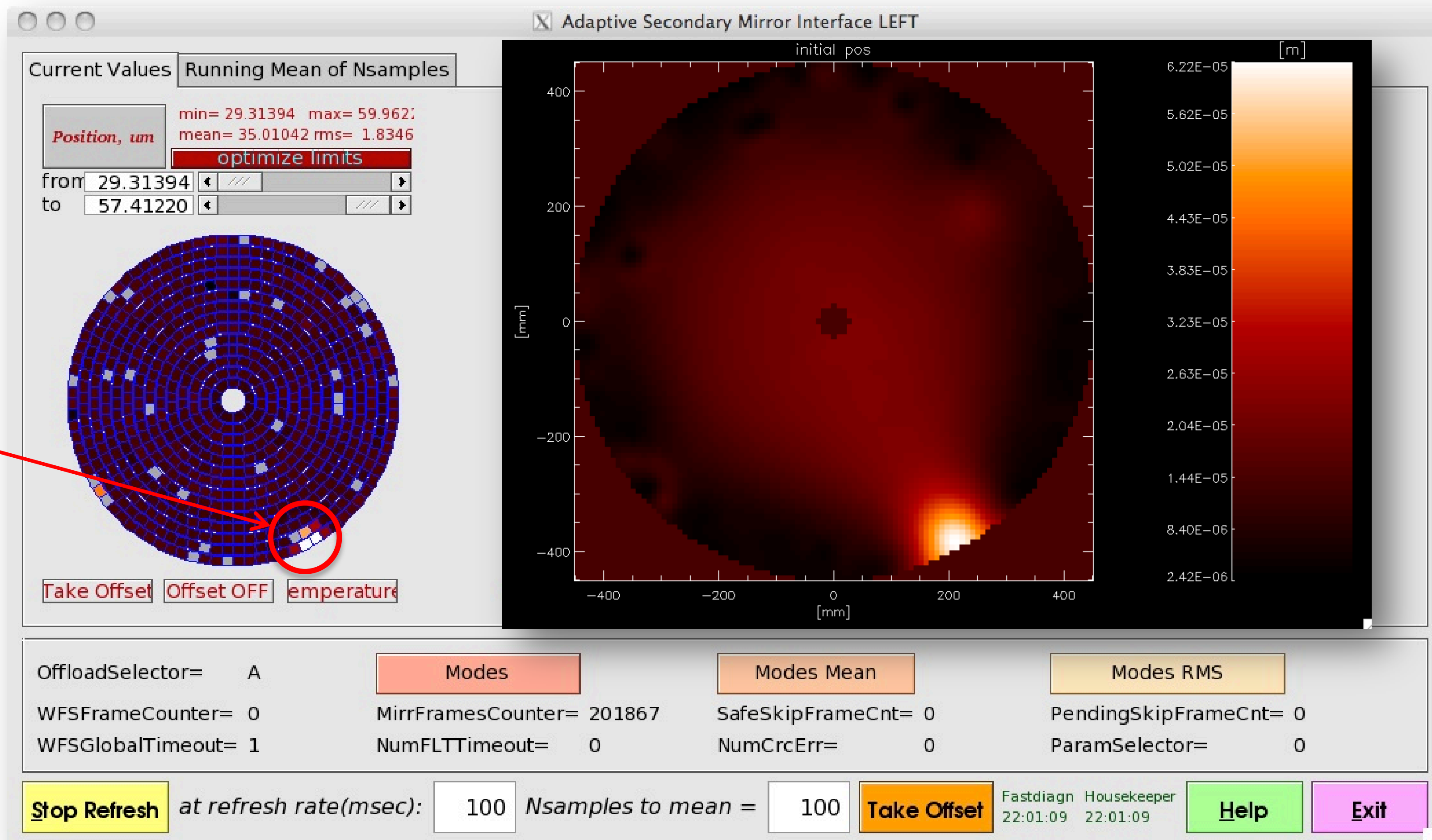
Adaptive Secondary Failure Modes

- Major failure modes in the last year requiring significant intervention:
  - DX Unit (right side)
    - Overcooling Event
      - Valve stuck open & temperature dropped ~17C in ~ 1 hour
      - Condensation on shell surface which then froze
      - As the unit was warmed up, the melting ice “wicked” into the gap between the shell & the reference body.
      - Required replacement of shell (TS4 for TS3)
      - Major overhaul of electronics, actuators & contacts
    - “Pie” Shape
  - SX Unit (left side)
    - Gap Contamination
    - “Pie” Shape

Adaptive Secondary Failure Modes

- Gap Contamination:

Actuators at the edge of the ASM show a large positional error.



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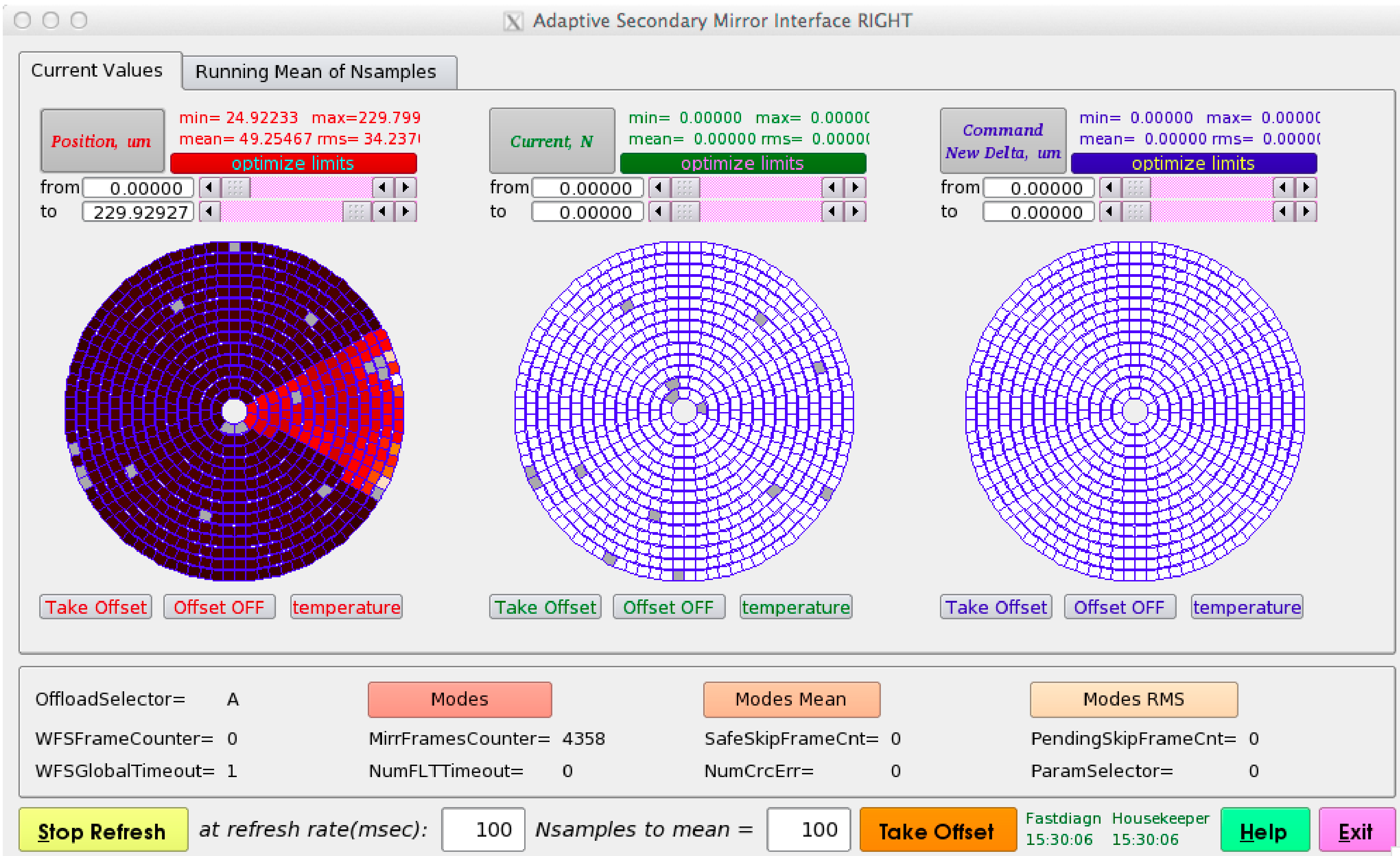
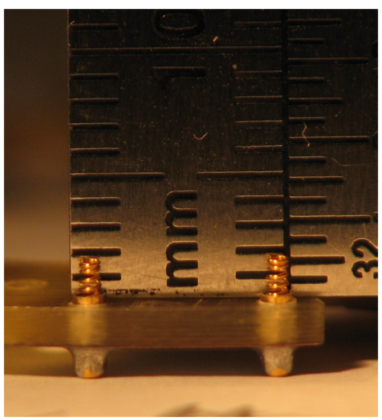
Adaptive Secondary Failure Modes

- The “Pie” shape:
  - So-called because of a failure in the electronics or distribution board controlling 1 of 6 sectors of the DM
  - Intermittent to begin with …

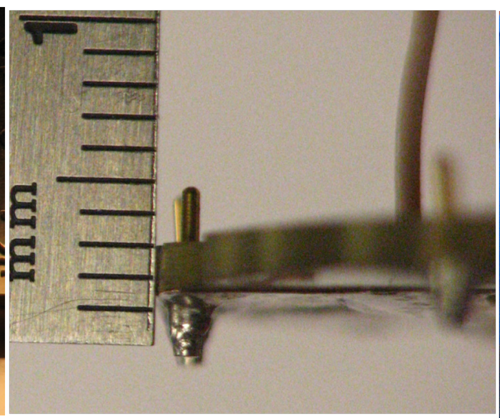


Adaptive Secondary Failure Modes

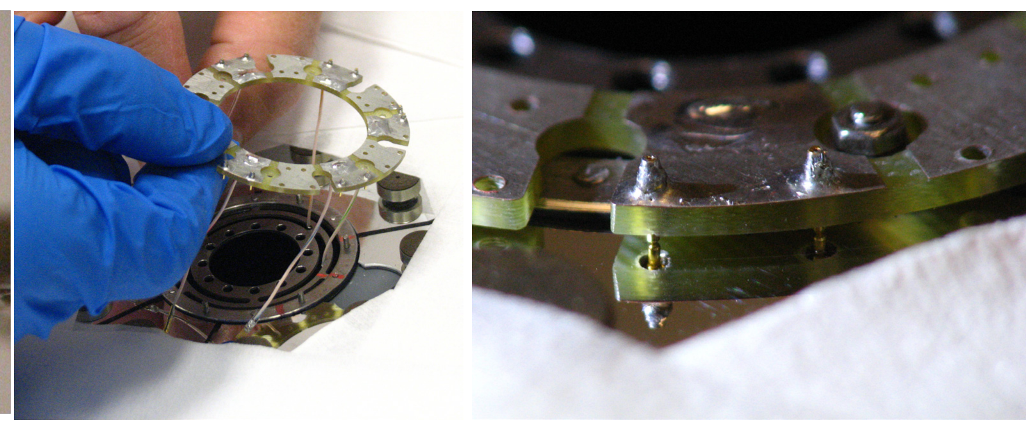
- Mitigation of the “Pie” shape:
  - Open circuit because of a poor connection on the Central Distribution Board. This board carries the signal for the actuator control to the six individual sectors on the back side of the thin shell.
  - For the SX unit the spring contacts were cleaned and replaced.
  - 5 months later the DX unit showed identical behavior.
  - Springs were replaced by pins (used in the VLT unit).
  - Failed after only two days.
  - Currently working on putting back the springs, researching other options (different coating material, improved springs, etc.).



Spring Contacts



Pin Contacts



Central Distribution Board

Summary

BENEFITS

- Increased FoV
- Provide high-order correction
- Reduced background for NIR/MIR Observations
- Feeds all focal stations

COSTS

- Are exposed to the environmental conditions
  - temperature and humidity variations
  - wind speed restrictions
  - protection from contamination *
  - require cooling and power *
- Intrinsically complex technology
  - Still maturing *
  - "wear and tear" appears more rapid than expected
    - Detached magnets
    - Contamination
      - » coating on back-side of shell
      - » Actuator contacts
  - Elevation restrictions > 25°
- Unit Calibration
- Have delicate optical components
  - need to minimise handling
- Expensive
  - spare unit, spare shell

MITIGATION

- Regular monitoring & maintenance
- Shell cleaning & recoating
- Hardware upgrades
- Firmware & software upgrades
- Spare Components