THE UKIRT UPGRADES PROGRAMME

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ORIGINS OF THE UPGRADES PROGRAMME

- **UKIRT was designed to be cheap,**

SO:

- **IT HAD A THIN *(FLEXIBLE!)* PRIMARY**

which was figured until the ££££ ran out – Grubbs had mastered polishing it, so the *result was very good*

- **IT HAD THE SMALLEST POSSIBLE DOME**

which should therefore be *easy to ventilate*

- **IT HAD THE LIGHTEST POSSIBLE STRUCTURE**

and so had *lower thermal inertia* than any similar-sized telescope

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TELESCOPE

… INSTEAD OF A LIGHT-BUCKET

ORIGINS OF THE UPGRADES PROGRAMME (Continued)

However, despite its potential, UKIRT had many problems:

- POINTING was not very good
- TRACKING was unreliable at arcsec levels, and
- ... badly affected by WINDSHAKE in modest winds
- OPTICAL ALIGNMENT was poor and hard to correct
- Top-end design led to POOR THERMAL IR PERFORMANCE
- THERMAL PLUMES could be seen in out-of-focus images, so dome seeing was probably poor

ORIGINS OF THE UPGRADES PROGRAMME (Continued)

The result was a telescope that was hard to use for programmes requiring high angular resolution, indeed…

Early instruments were especially designed to be suited to low-resolution applications

(which actually lead to some unique observations, e.g. global line strengths of galaxies)

ORIGINS OF THE UPGRADES PROGRAMME (Continued)

These problems were not easy to fix, e.g:

- Andy Longmore and Bill Parker worked on the telescope drive servo for years, but could not get good performance over the sky:
If the servo was stiff to windshake in one part of the sky it tended to oscillate in others

ORIGINS OF THE UPGRADES PROGRAMME (Continued)

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(The Devil makes work for idle hands???)

UKIRT Upgrades Overview

- Project approved by the UKIRT Board in September 1991
- Multi-year collaboration involving 4 groups: ROE, RGO, MPIA (Heidelberg) and the JAC.
- For most of the programme the core group at the JAC were:
  - Nick Rees: optics, computing, control systems
  - Tim Chuter: electronics, optics, operational issues
  - Chas Cavedoni: JAC Project Manager, Mechanical engineering
  - Tim Hawarden (me): (JAC) Project Scientist (optics, aO, AO, science operations, scientific direction).

  … helped at one time or another by most of the JAC technical staff and about half of ROE…
- From 1993 the overall project manager was Donald Pettie at the ROE
- More than 30 people were significantly involved at the four Institutes… very hard to apportion fair credit!

MAJOR UNOFFICIAL CONTRIBUTION:

- We freely plagiarised from the IRTF upgrades programme (starting by poaching their engineer, Chas Cavedoni)

- For several years we let them make the mistakes first…

- Then we (mistakenly?) overtook them and had to start making our own blunders…

GOALS OF THE PROGRAMME:

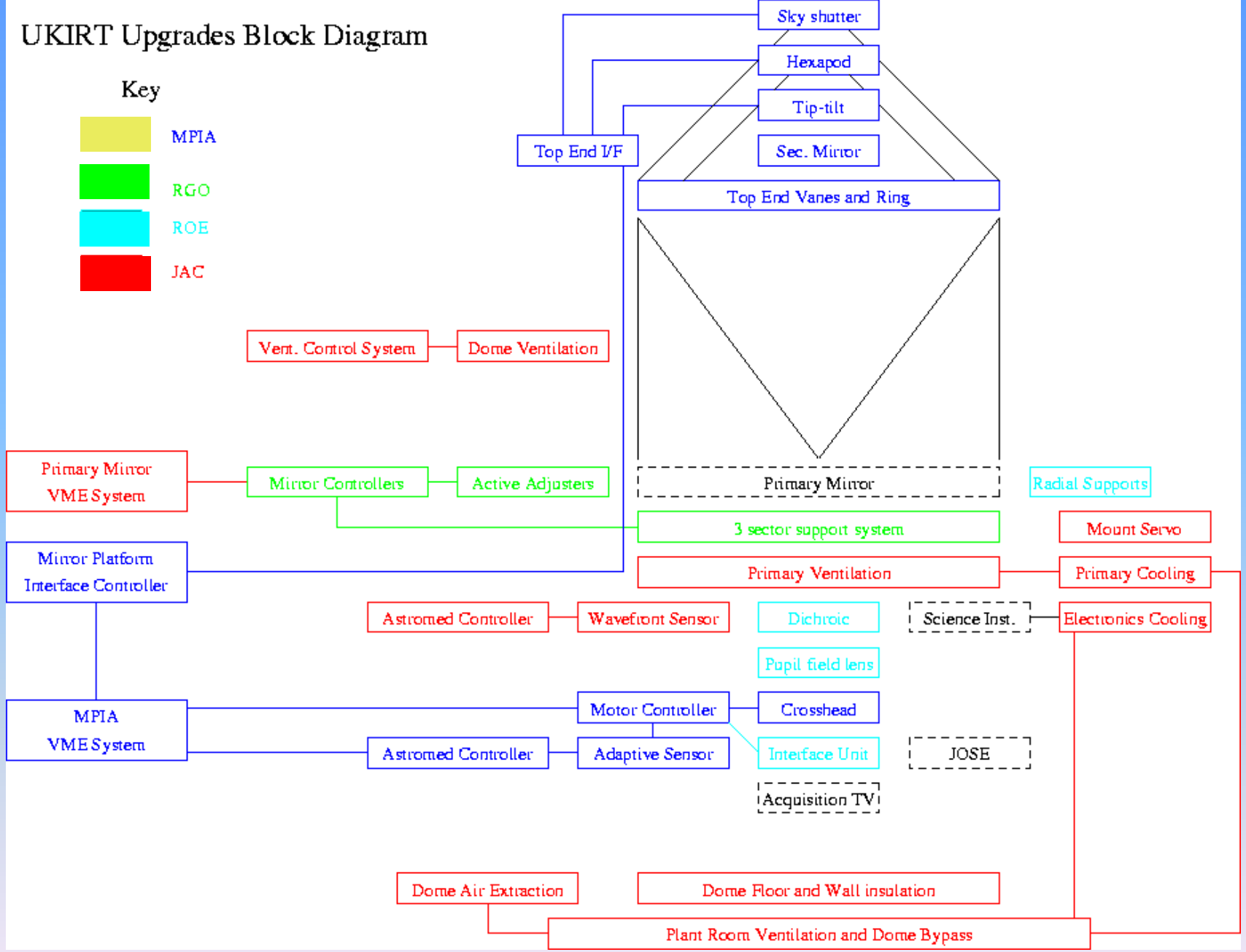
- **UKIRT *must* not degrade the delivered image quality by more than 0.”25 (measured as FWHM)**
  (this was the predicted image size for a tip-tilt corrected 4m telescope at K in median MK conditions)

- **UKIRT *should* not degrade the delivered image quality by more than 0”.12 (measured as FWHM)**
  (this is the diffraction limit of UKIRT in the K band)

- **Local seeing effects *should* not appreciably degrade image quality**

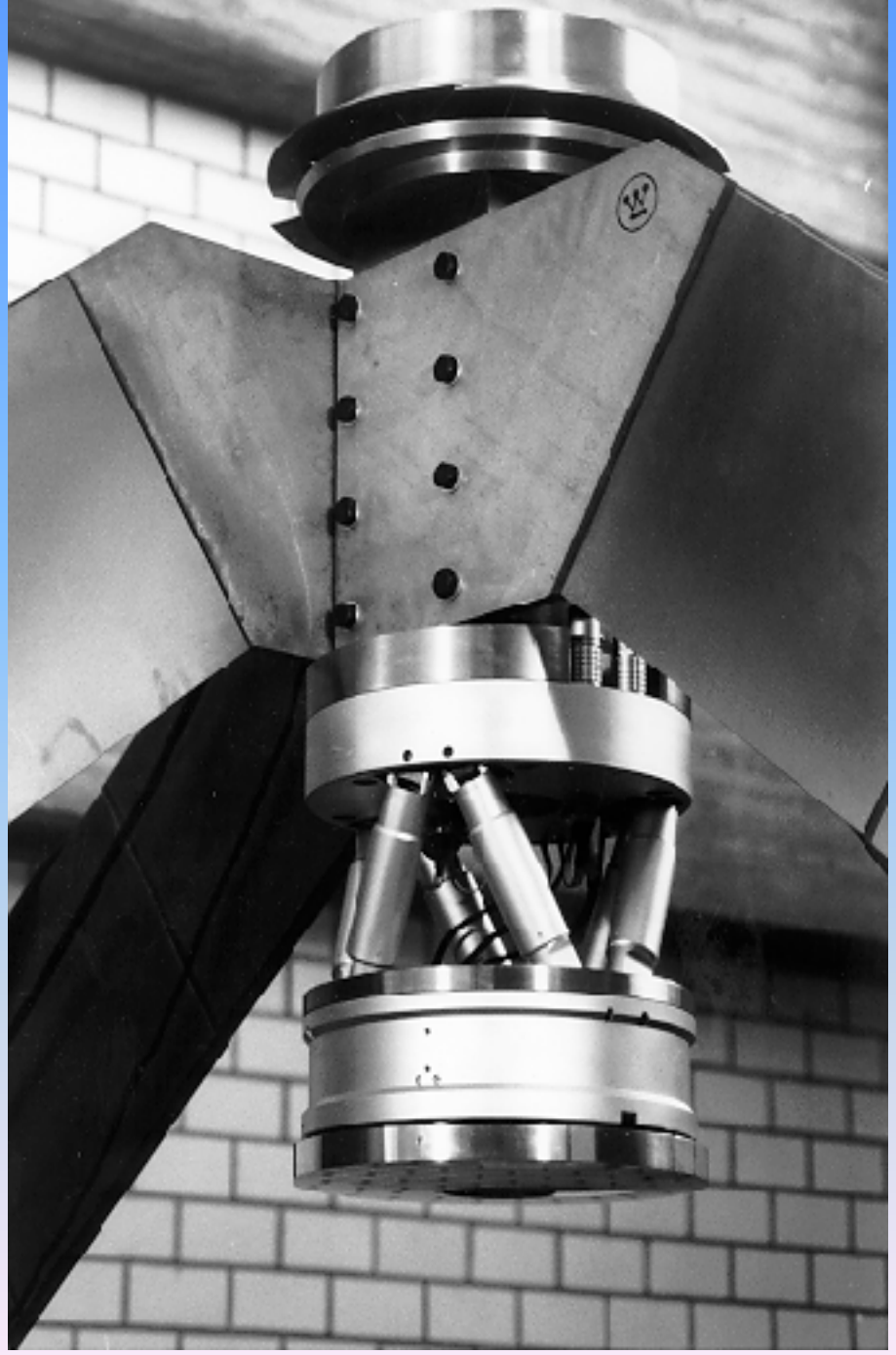
MAJOR ELEMENTS OF THE UPGRADES

- Fast two-axis tip-tilt Secondary Mirror with accurate positioning, on a new, stiff, top-end, to correct image motion (esp. windshake!)
- Sensitive CCD-based fast guider (>200Hz)
- Active control of Primary Mirror aberrations
- Control of local seeing by ventilating the dome and primary mirror, and by actively cooling the latter


UKIRT Upgrades Block Diagram
Key
MPIA
RGO
ROE
JAC
Sky shutter
Hexapod
Tip-tilt
Top End I/F
Sec. Mirror
Top End Vanes and Ring
Vent. Control System
Dome Ventilation
Primary Mirror VME System
Mirror Controllers
Active Adjusters
Primary Mirror
Radial Supports
3 sector support system
Mount Servo
Mirror Platform Interface Controller
Primary Ventilation
Primary Cooling
Astromed Controller
Wavefront Sensor
Dichroic
Science Inst.
Electronics Cooling
Pupil field lens
MPIA VME System
Motor Controller
Crosshead
Astromed Controller
Adaptive Sensor
Interface Unit
JOSE
Acquisition TV
Dome Air Extraction
Dome Floor and Wall insulation
Plant Room Ventilation and Dome Bypass

Secondary Systems (installed 1996)

- Light-weighted Mirror by Prazisions Optik (Germany)
- Control system provided by Physik Instrumente (Germany):
- Three axis fast piezo tip-tilt system with counterweight
- 6 axis “slow” hexapod positioning system



Secondary system attached to top-end structure and vanes*

(in lab at MPIA, Heidelberg)

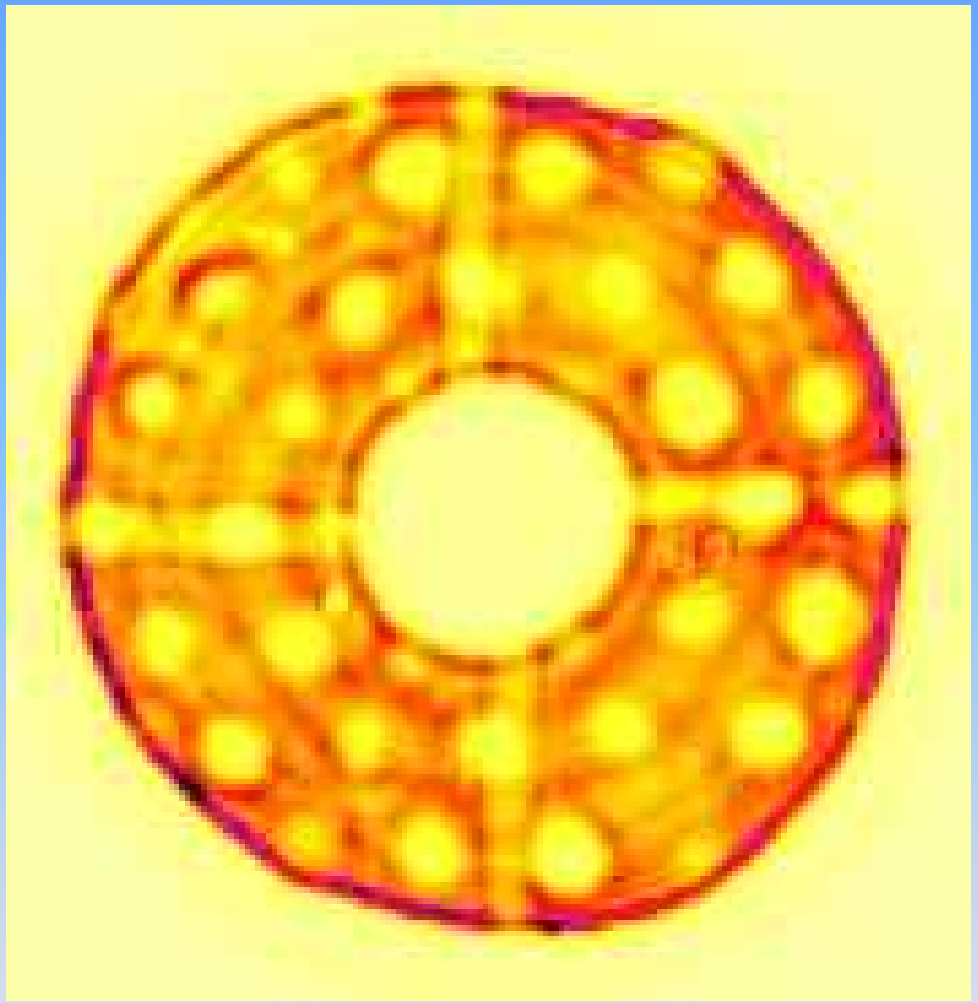
***note constrained-layer viscous damping!**

SERENDIPITY!

As well as improving thermal background stability (as intended), the new topend systems removed non-linear effects ("flop"):

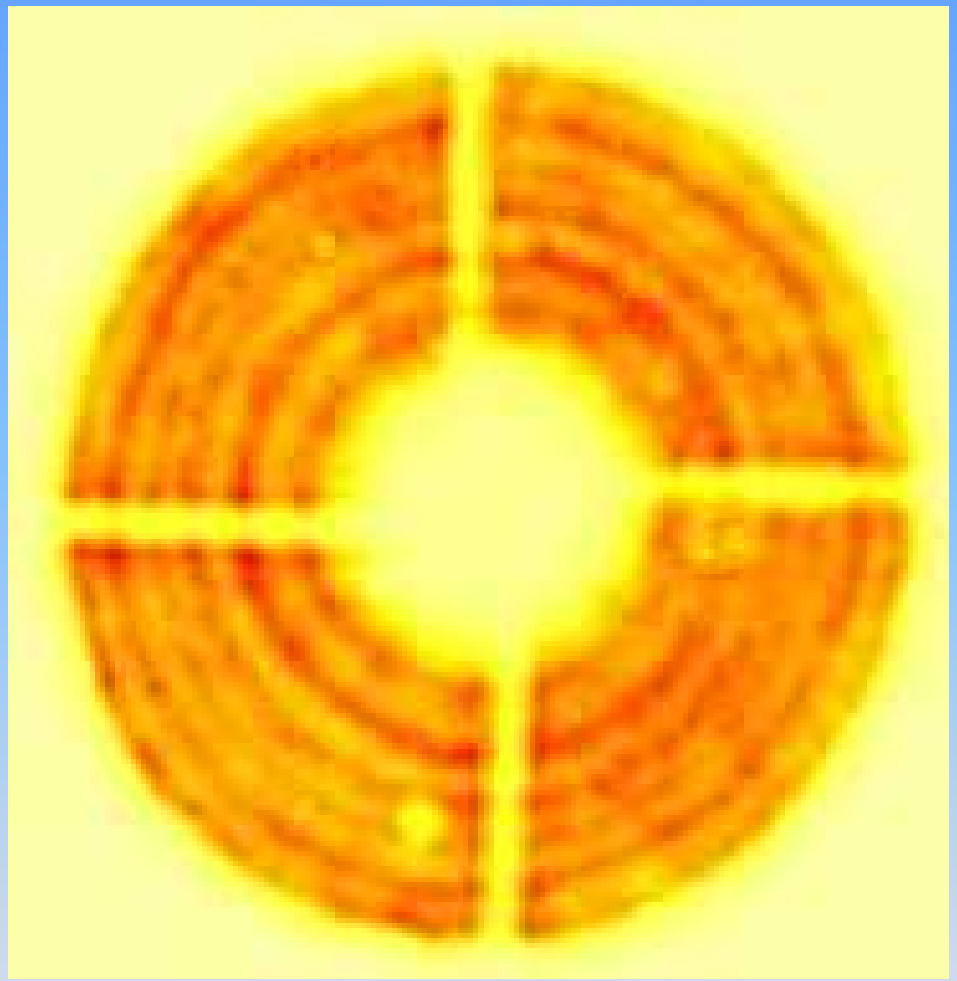
→ Greatly improved pointing (to ~1".3 RMS all sky)

→ UKIRT became best-pointing equatorially-mounted telescope in the world…



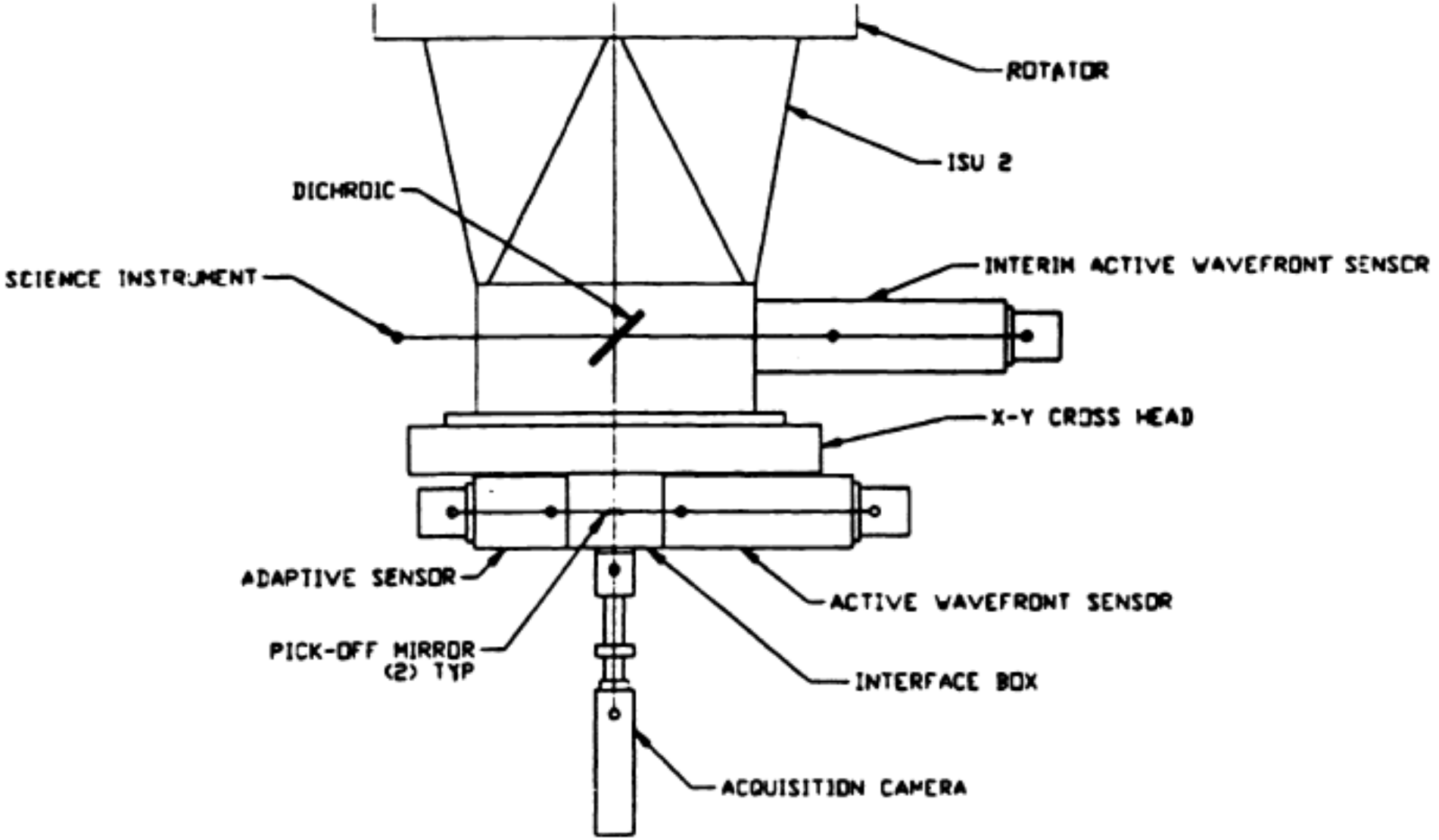
Cautionary Tale #1

Lightweighted secondary performed well, but had TDE and print-through of stresses, thermally induced trefoil (hard for primary to fix) and NBG for AO



SOLUTION:

- Replacement made over-size and edge ground off → no TDE
- Back etched for stress relief after lightweighting pattern ground in → no print-through
- New athermal mirror mounts removed trefoil



Bottom-end systems (fast guider,etc)

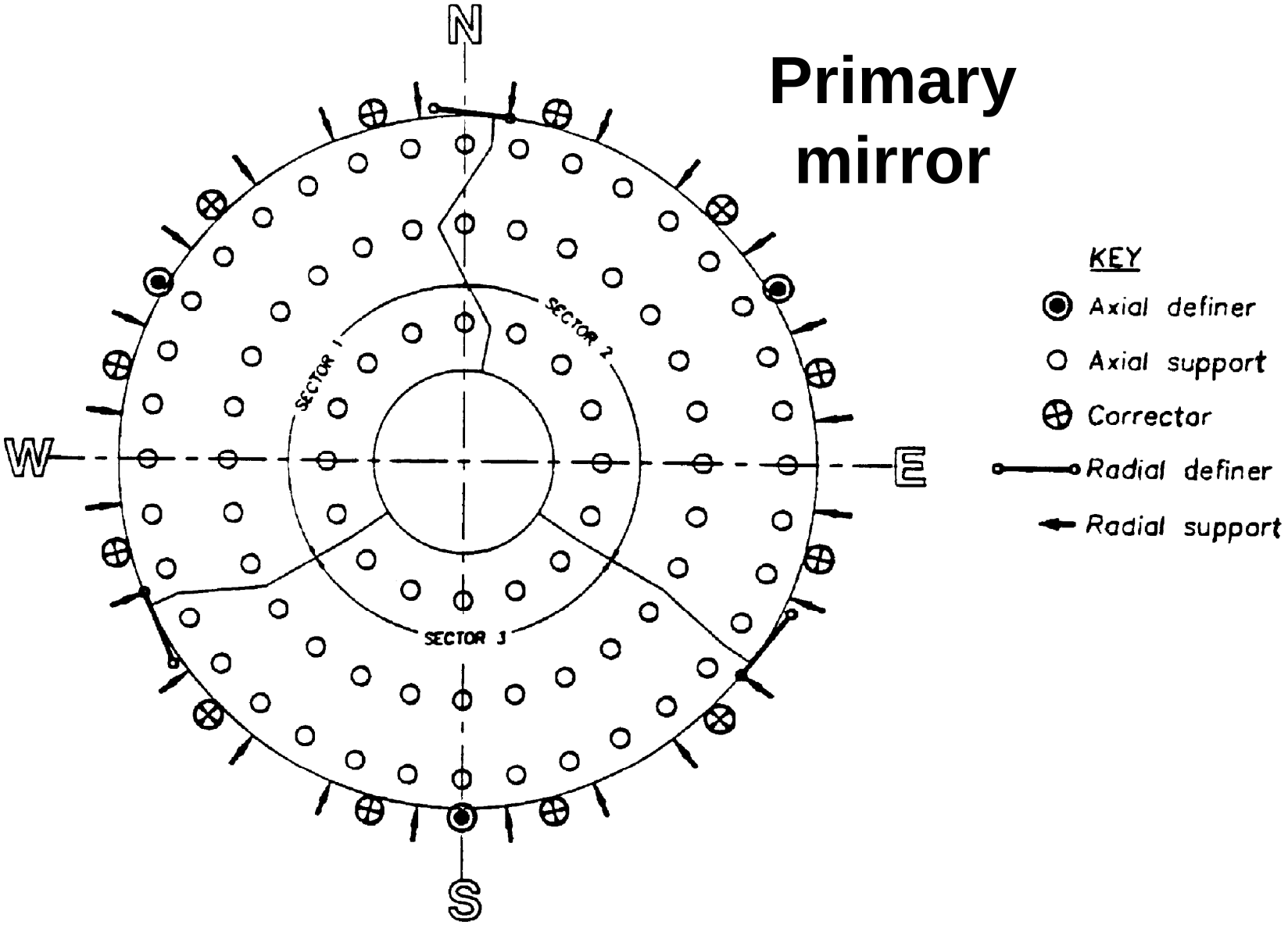
Bottom-end systems

- Interim wavefront Curvature Sensor for diagnostics and calibration of lookup tables
- New, very stiff and accurate crosshead (by SKF)
- Fast-guider using low-noise CCD, sophisticated Kalman filter, can hold image with ~10 c/cycle (can guide on V ~19.2 star at 40Hz sampling rate)
- Guider has acquisition mode, as well as autofocus capability and pure-seeing measurement facility
- TV camera gets 5% of photons from target….

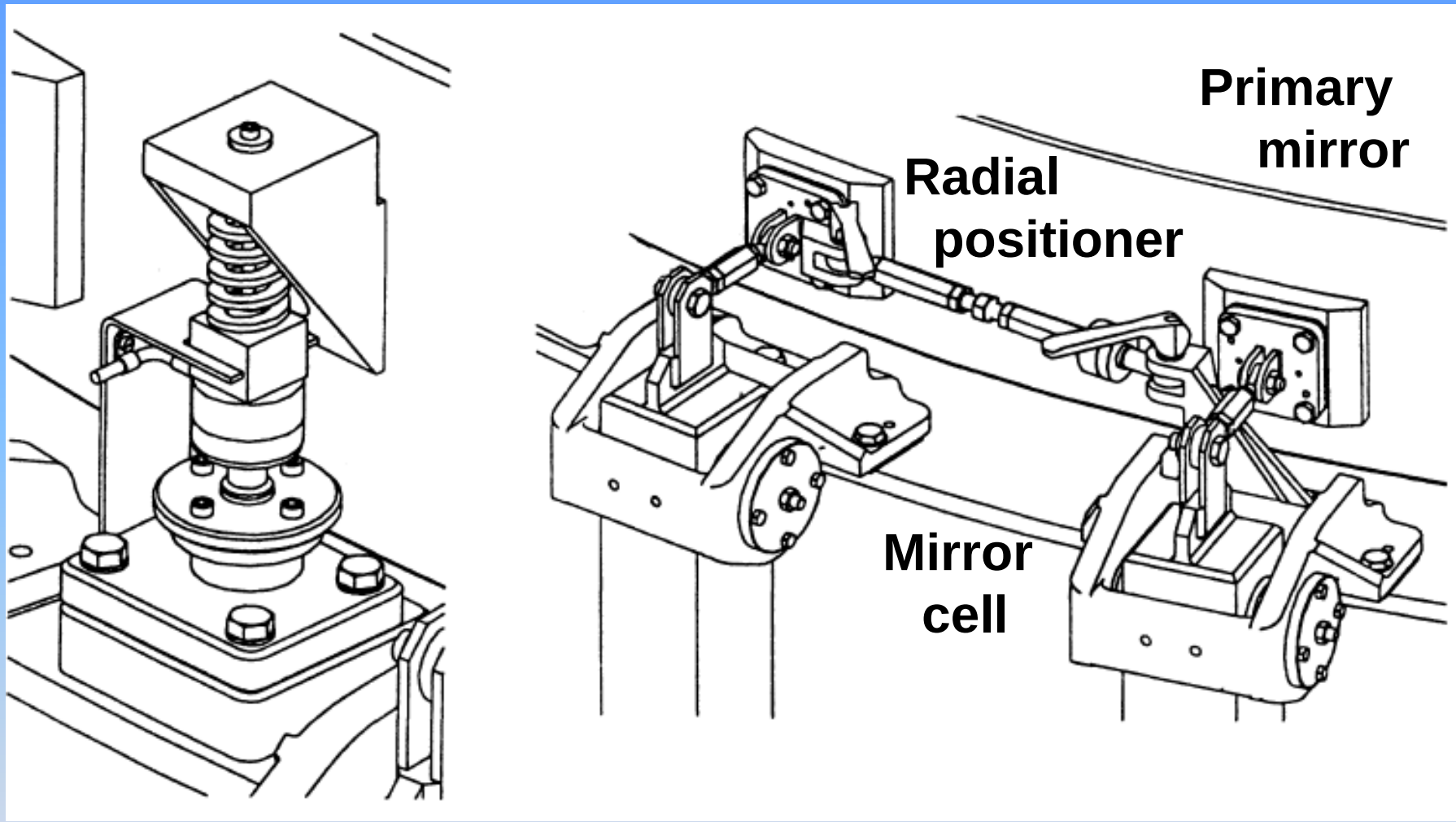
Mirror Support System

- Mirror must keep a figure to within <100 nm in all orientations
- Combination of
  - 3-sector axial support comprising of ~80 airbags servoing against the load on 3 axial definers.
  - Radial support consisting of 24 weights and levers
  - 12 point active pneumatic supports to take out systematic deformation
- All controlled over CANbus with the EPICS CAN driver

Primary mirror



Schematic of pneumatic axial support pads, edge supports, controllers and positioners

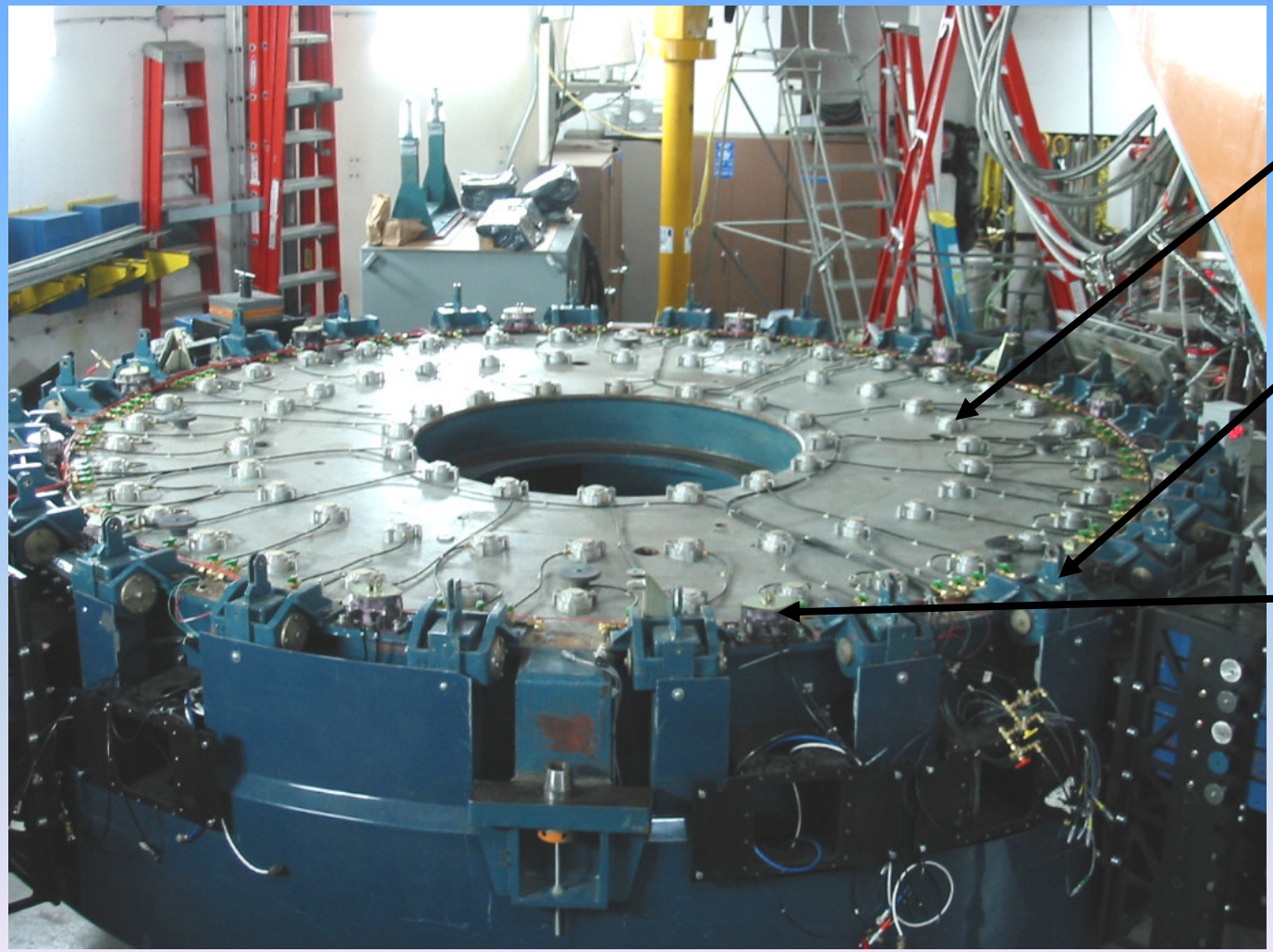


Active controllers

Radial support arm

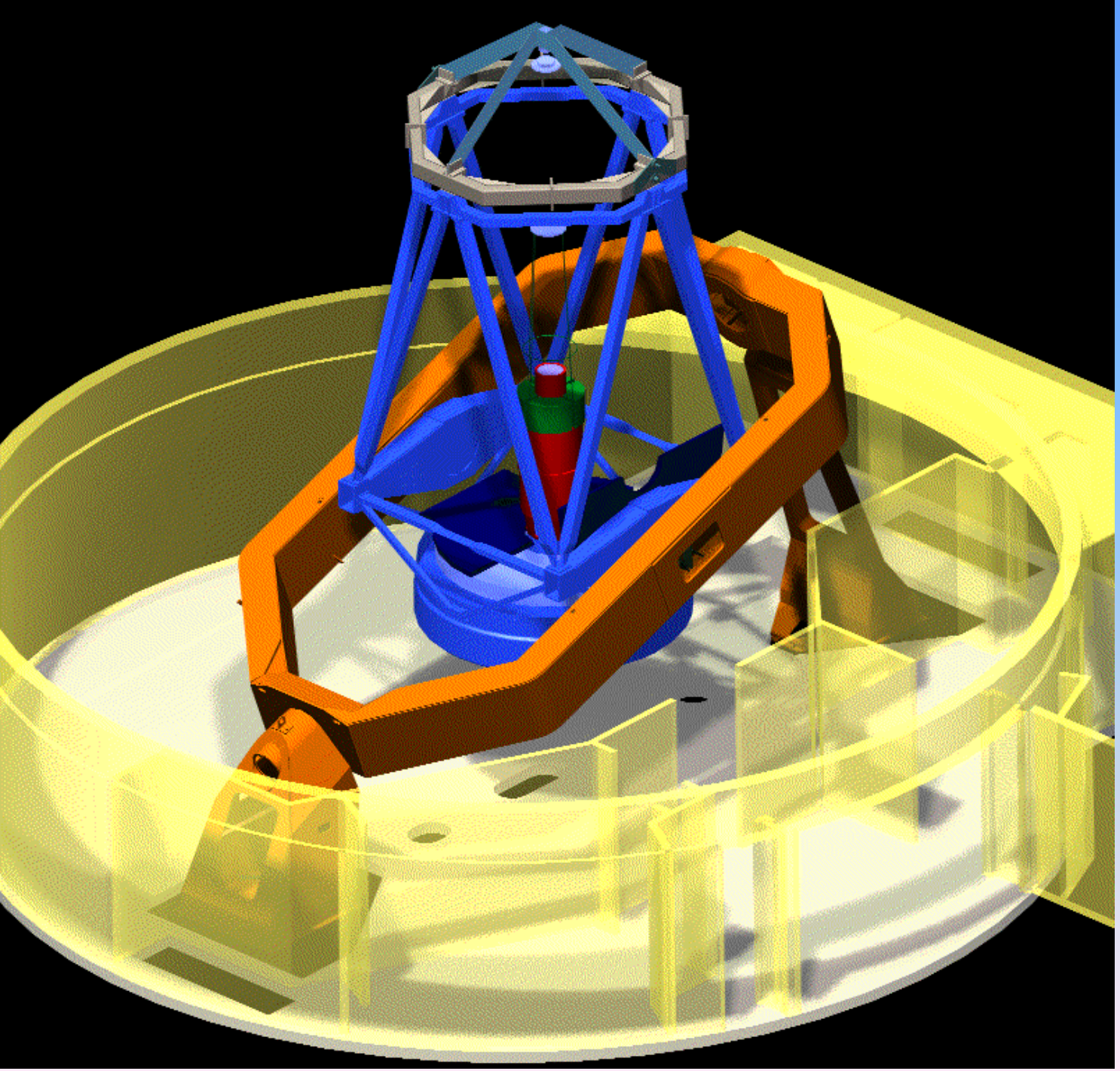
Radial support arm

Mirror Support System



LOCAL SEEING CONTROL

- **Dome insulation:**
  - **ceiling of crew rooms**
  - **vestibule around cargo entry area**
- **Dome ventilation**
  - **coude room as plenum chamber**
  - **boosted extractor fans in plant room**
- **Suppression of local sources**
  - **dispersal of instrument heat under primary**
  - **lo-mit paint on top-end central boss**
- **Mirror ventilation (interim): South Col fans**
- **Mirror cooling**
  - **radial flow from low-vibration fan**
  - **cooling and heating of air supply**



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Cautionary tale #2

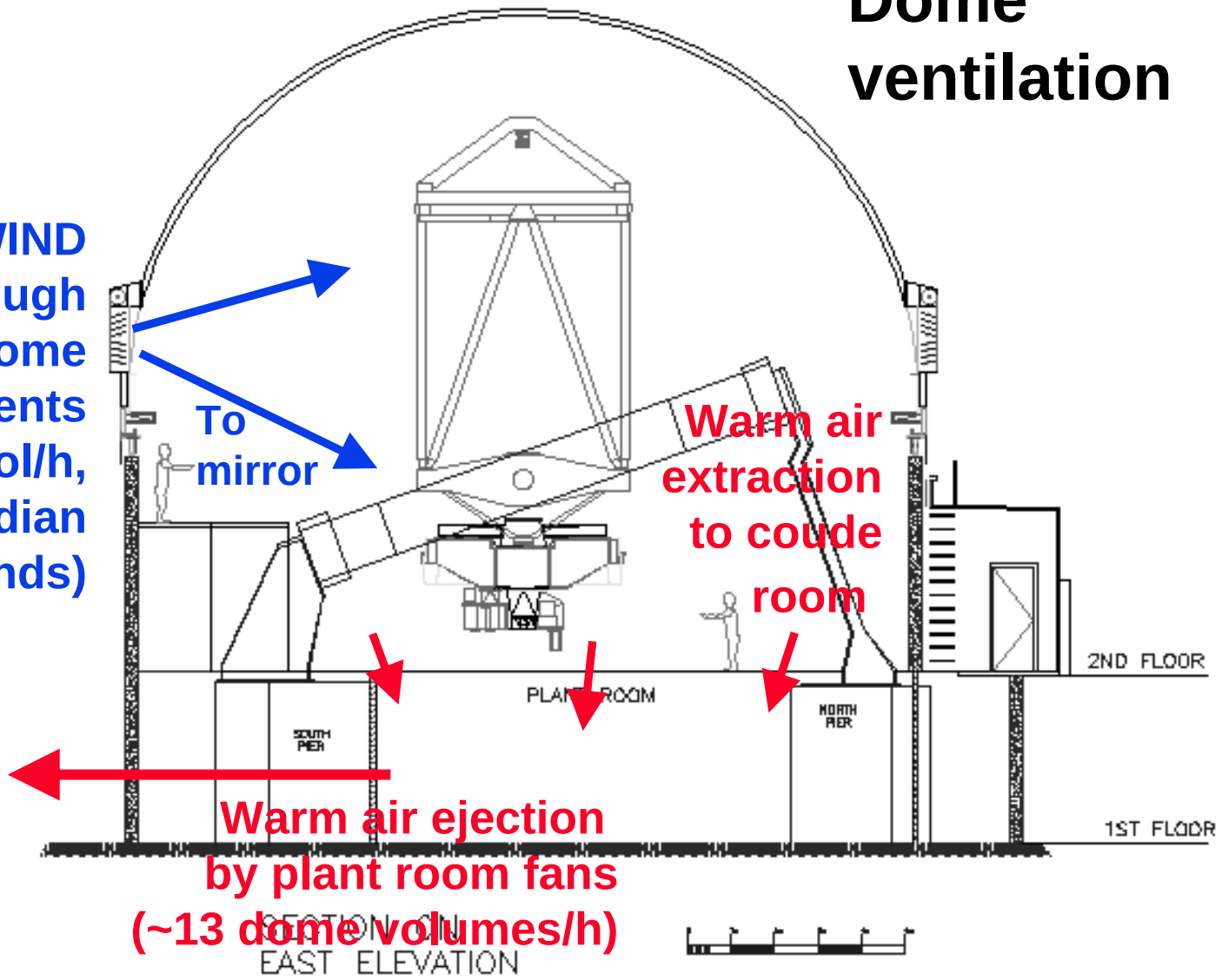
- We were about to place 4” of “inert” foam-backed board over the whole dome floor
- We got nervous after a glycol fire at CTIO, since primary cooling would use glycol
- Keck tested flammability at altitude: HIGHER than at sea level for almost all materials!

→Glycol spillage → fire hazard → dome floor still concrete…

LOCAL SEEING CONTROL

- Dome insulation:
  - ceiling of crew rooms
  - vestibule around cargo entry area
- Dome ventilation
  - 16 louvred vents in dome
  - coude room as plenum chamber
  - boosted extractor fans in plant room
- Suppression of local sources
  - dispersal of instrument heat under primary
  - lo-mit paint on top-end central boss
- Mirror ventilation (interim): South Col fans
- Mirror cooling
  - radial flow from low-vibration fan
  - cooling and heating of air supply

Dome ventilation



LOCAL SEEING CONTROL

- Dome insulation:
  - ceiling of crew rooms
  - vestibule around cargo entry area
- Dome ventilation
  - coude room as plenum chamber
  - boosted extractor fans in plant room
- **Suppression of local sources**
  - **dispersal of instrument heat under primary**
  - **lo-mit paint on top-end central boss**
- Mirror ventilation (interim): South Col fans
- Mirror cooling
  - radial flow from low-vibration fan
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LOCAL SEEING CONTROL

- **Dome insulation:**
  - ceiling of crew rooms
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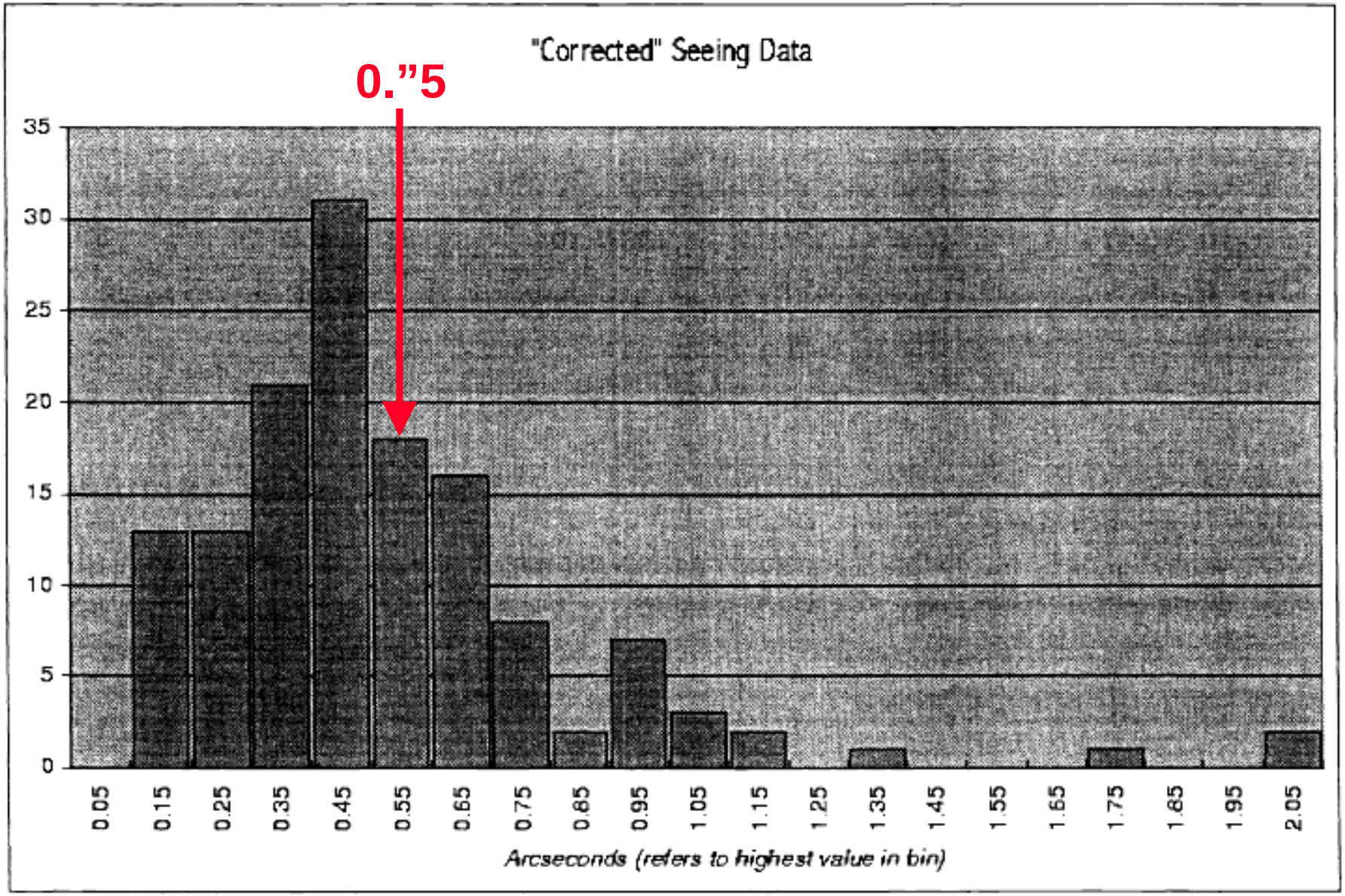
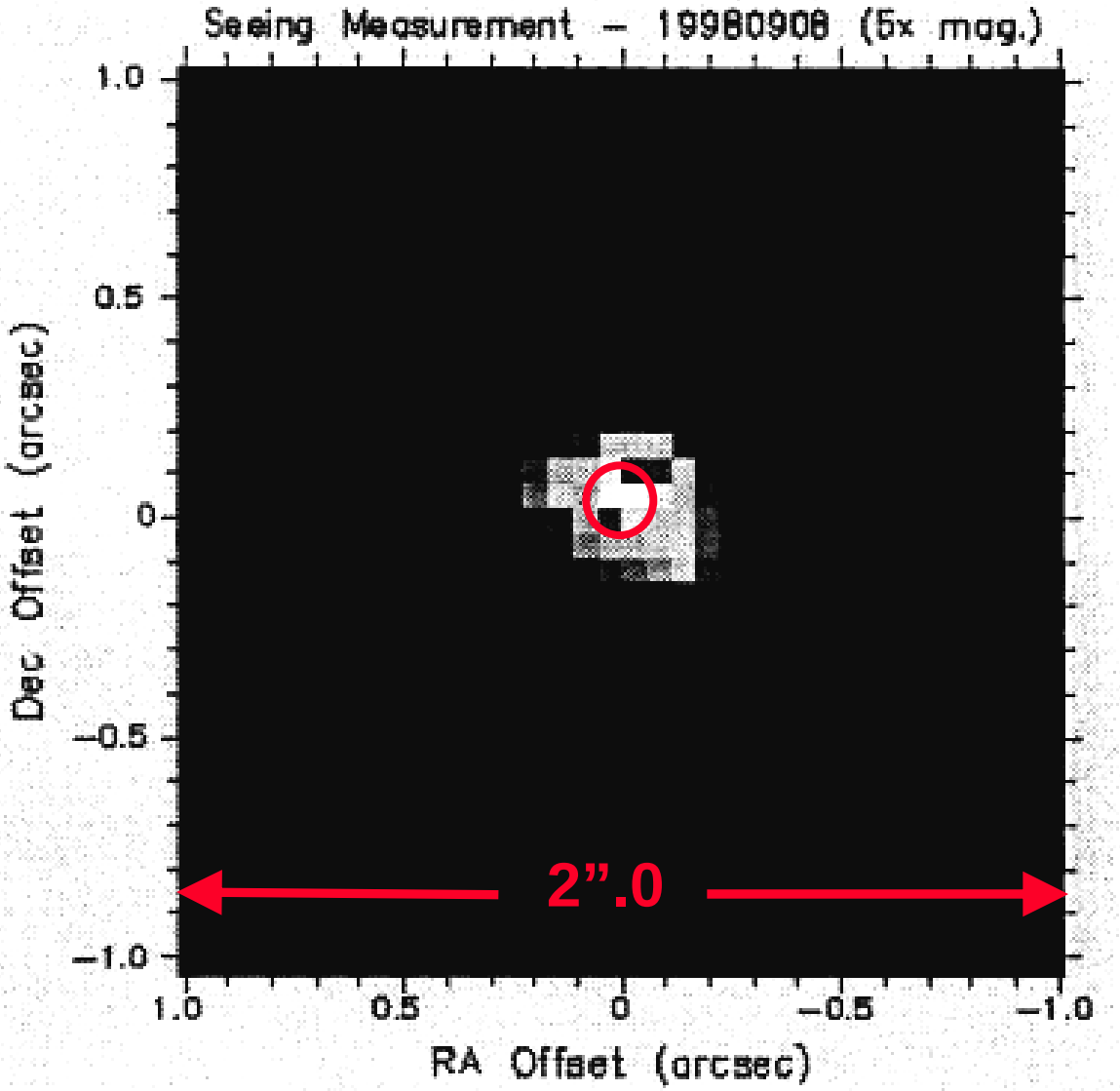
- **Dome ventilation**
  - coude room as plenum chamber
  - boosted extractor fans in plant room
- **Suppression of local sources**
  - dispersal of instrument heat under primary
  - lo-mit paint on top-end central boss
- **Mirror ventilation (interim): South Col fans,**
  - **louvre-directed flow from DVS apertures**
- **Mirror cooling**
  - radial flow from low-vibration fan
  - cooling and heating of air supply

LOCAL SEEING CONTROL

- **Dome insulation:**
  - ceiling of crew rooms
  - vestibule around cargo entry area
- **Dome ventilation**
  - coude room as plenum chamber
  - boosted extractor fans in plant room
- **Suppression of local sources**
  - dispersal of instrument heat under primary
  - lo-mit paint on top-end central boss
- **Mirror ventilation (interim):** South Col fans,
  - louvre-directed flow from DVS apertures
- **Mirror cooling (not yet???)**
  - radial flow from low-vibration fan
  - cooling and heating of air supply

RESULTS!


"Corrected" Seeing Data
0."5
35
30
25
20
15
10
5
0
0.05
0.15
0.25
0.35
0.45
0.55
0.65
0.75
0.85
0.95
1.05
1.15
1.25
1.35
1.45
1.55
1.65
1.75
1.85
1.95
2.05
Arcseconds (refers to highest value in bin)



1998 Sept 7:

This K image has FWHM 0”.171 (circle):

At that time, the best ground-based non-AO* image ever taken!

*MK has small L_0 so tip-tilt doesn’t really do AO

UKIRT AFTER THE UPGRADES