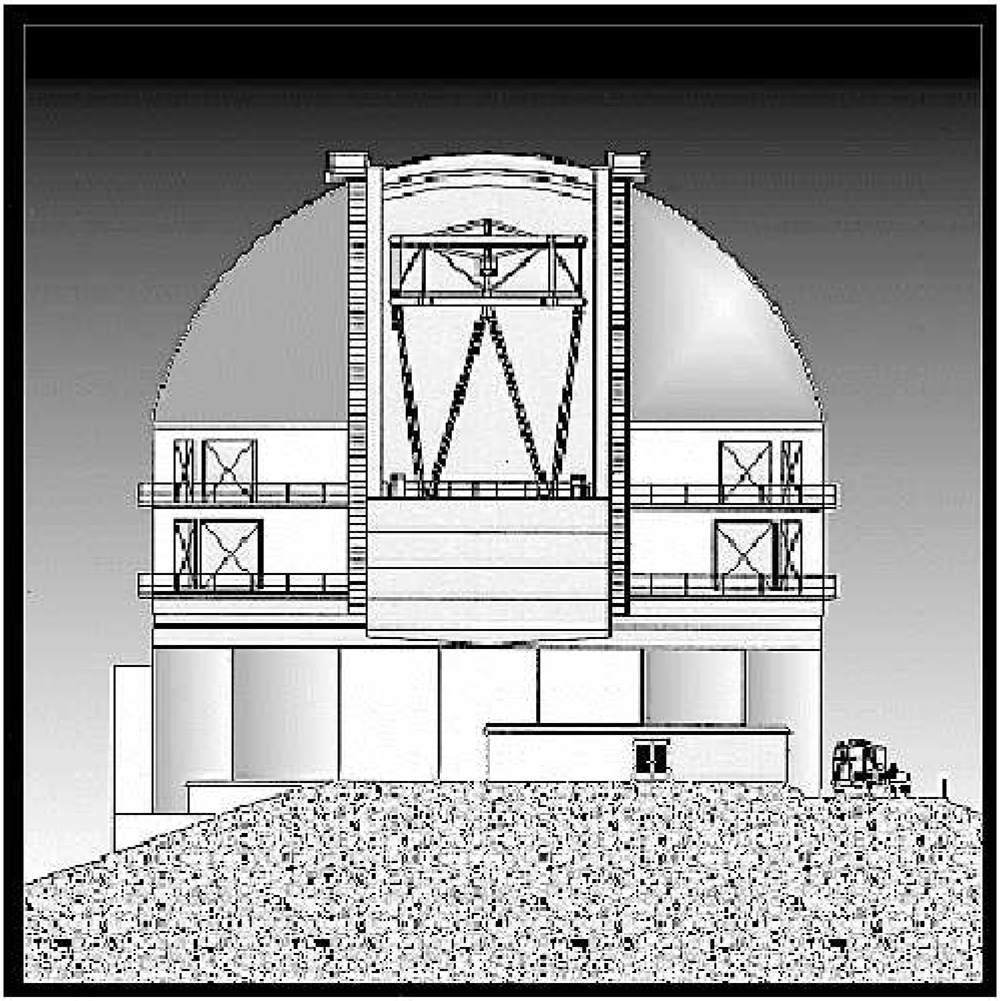
GEMINI
8-M Telescopes
Project

RPT-O-G0050

Mirror Technology Workshop



March 1-3, 1993

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Mirror Technology Workshop
RAL, Abingdon, U.K. and ESO, Garching, Germany
March 1 - 3, 1993

1. Meeting at Cosenors House, RAL

Representatives of the Gemini and Subaru project office gave a brief summary of the present status of these projects. This was followed by presentations of the error budgets, leading to more detailed discussions on coping with wind buffeting of the primary and thermal control to minimize mirror seeing.

To deal with wind buffeting one needs information on the magnitude, frequency domain and load distribution. The mirror deflection/distortion, whether spherical, piston, small scale, etc., then depend on its stiffness, type of axial support and the number and locations of its defining points. Sensing these deflections can be by optical means using real stars or other means, using targets at the front or the mirror rear surface, or by load cells located on the defining points and/or distributed on the axial supports. Provided the information can be gathered and processed rapidly, it might be feasible to design servo systems that can cope with wind buffeting, however, such a system might need additional damping mechanisms. Alternatively, a passive overconstrained axial support system may be relatively insensitive to wind loading, provided the mirror cell is very stiff.

On mirror seeing there is some confusion about the exact relationship of the temperature difference between the mirror and the ambient air with seeing, and how this relationship is modified by external wind conditions and mirror inclination angle.

The Gemini axial support and thermal solutions consist of:

- an airbag that supports 80% of the mirror weight but varies with zenith angle
- a hydraulic whiffle tree, 3 zone and/or 6 zone, that acts as a defining system
- a passive axial support system of 120 units that supports 20% of the total mirror weight at any zenith angle
- a hydraulic system that restricts fluid exchange between individual units thereby making the system insensitive to wind loading
- design allows for 11 m/sec. external wind, 3 to 4 m/sec. wind at mirror, equivalent to $1.7 N/m^2$ RMS (spatial) pressure
- active support mechanisms, mechanical or pneumatic, attached to all axial and tangential supports for fine tuning support forces
- load cells at all active support mechanisms
- a very stiff mirror cell consisting of welded box construction
- provision for pre-cooling mirror blank by 2 to 3 degrees C
- provision for heating mirror reflective surface with warm air in order to match ambient temperature
- investigation to heat mirror surface electrically by passing current through mirror coating

The Subaru axial support and thermal solutions consist of:

- active axial mechanical support system consisting of 264 independent units, spaced in 8
- concentric rings
- each unit weighs 70kg and is 1.6m long
- wind loading measured by load cells at three fixed defining points
- can compensate for only first three modes of wind loading: tip, tilt, piston
- dome design and wind screens will reduce wind speed at mirror to 2m/sec.
- provision for pre-cooling mirror blank for thermal control - "great wall"
- enclosure vertical interior partitions/side walls plus variable slit are used for natural flushing of hot (cold) air bubbles from telescope structure and enclosure

RGO and independent studies.

- have looked at pneumatic active axial support system
- 264 independent units, each with its own control valve
- 60 distributed load sensors plus three on fixed defining points to measure wind loading
- FEM analysis shows that +/- 100g actuator error can destroy image, aiming for 15g accuracy
- can sample load cells at 50Hz, can control pneumatically to 8Hz
- load cells at 70kg good to +/- 5g but require calibration, stiffness at .001 mm/ 10N is high
- mirror cell requires stiffness at three defining points only, actuators allow for 5mm differential displacement
- requires additional damping provision to cope with wind loading
- requires dynamic analysis and servo control solutions
- suggesting a very methodical laboratory approach to seeing evaluation and additional test of mirrors in real enclosures

Summary

The three approaches for the mirror support can be summarized as follows:

Subaru - Load cells on three defining points provide insufficient information for non-uniform wind load correction.

Gemini - Combines a passive hydraulic system with a stiff mirror cell to cope with non-uniform wind loading. Project needs to decide on the type of system for measuring wind loading on Mauna Kea. Nine zone whiffle tree support needs to be investigated and might provide for overall better performance.

RGO - Pneumatic system requires cell stiffness at only the three defining points. Wind loading is sensed by numerous load sensors. Requires development of damping units and servo control solution.

Thermal control

- disagreement on seeing/temperature differential relationship indicates that further investigations are necessary
- thermal heating through coating requires investigation into emissivity and corrosion behavior
- extensive thermal data at CFHT needs to be processed and analyzed

2. RAL tour

The participants were given a brief tour of the design and manufacturing facilities of RAL as well as tour of the nuclear synchrotron establishment. Also, for this tour RGO had moved its experimental pneumatic mirror support system to RAL. This system utilized a thin 1m steel dummy mirror on nine axial and three radial supports. One axial support was fully instrumented and under servo control. With a 100g load placed in the vicinity of this support, the control system was able to compensate deflection, but required several seconds.

Handouts on the system concept and technical illustrations were not provided.

3. Meeting at Garching, ESO

Representatives of ESO gave a brief account of the current status of their project. Bids for the detailed design and construction of the MI unit had been received from six companies and ESO was to make the final decision on a manufacturer during this week. They are trying to negotiate a contract that permits them to have improvements as they arise to the methods of thermal control and wind loading attenuation. ESO maintains a full size engineering group, about six people, for MI during the detail design, construction and testing phase. This includes optical, thermal and FEM analysts, mechanical designers and software/controls specialists.

Bids for the detail design and construction of the enclosures had also been received and the closing date for these was in the same week.

The ESO VLT mirror axial support system solution consists of:

- 150 axial supports on a hydraulic, three zone, whiffle tree arrangement
- support forces are further distributed by incorporating a tripod arrangement at each axial support giving in effect 450 axial supports
- tripods attach to bonded pads on mirror, this approach minimizes support print through to 6nm rms
- the mirror cell is a light-weight space frame that is not very stiff and weighs only 10,500kg, compared to the mirror at 23,500kg
- each of the 150 axial support units consists of a passive hydraulic portion as well as an active electro/mechanical active portion

- during operation (zenith to 70 degrees) the passive force can vary from 500 to 1,600N and the active portion from -500 to +800N
- enclosure must limit wind speed to 1.35 to 2.6m/sec depending on the zenith angle.
- design allows for $1N/m^2$ RMS (spatial) wind loading
- Shack-Hartmann image analyzer considered not adequate for frequencies above 3 Hz, other methods are currently being investigated
- wind buffeting not a problem for 90% of the time
- will have thermal control of primary mirror surface to 1 degree C by combination of heat exchange with cooling blanket on mirror cell and heating/cooling of front face with controlled air

4. Comparison of image quality budget

ESO - at 500nm, 0 to 70 degrees zenith distance, 9m/sec average wind speed
- overall 0. 844CIR - 0. 1 15 " (in radius, 50% energy)
- local seeing - 0.979CIR - 0.041 " (in radius, 50% energy)
- wind loading - 0.024CIR - 0.024" (in radius, 50% energy)

Gemini - 1 arc minute field, zenith pointing
- overall - 0. 10" (in diameter, 50% energy)
- local seeing - 0.052" (in diameter, 50% energy)
- wind loading - 0.030" (in diameter, 50% energy)

Subaru - overall - 0.23" FWHM - 1.01" rms
- mirror seeing - 0. 12" FWHM
- wind loading - 0.064"FWHM

Note: CIR = peak intensity in PSF with real telescope / peak intensity in PSF with perfect telescope
- (real telescope incl. all errors plus atmos. turbulence)
- (perfect telescope has atmos. turbulence only)
- 50% = Means that 50% of the energy is enclosed by a circle of 0. 10 arcsec diameter (or radius)

5. Future meetings

Unanimous agreement was expressed in having future meetings of this type since the yearly conferences are very cumbersome and do not lend themselves to easy exchange of information and frank discussions on common problems faced by each group. Representatives from the various project groups should meet every three months to review progress and to discuss continuing and new technical issues common to all.

6. Gemini Tucson project office and U.K. involvement.

The project is soon entering the detail design and construction phase and it is appropriate that the partner countries assume a more direct involvement in the project by taking responsibility of some of the major work packages. The U.K. has expressed interest in taking over the design and construction of the MI unit, which includes the axial and tangential support system, the mirror cell, the temperature sensors and thermal control system, the wind loading sensor and servo control for wind buffeting. The primary mirror support and cell is without doubt a key ingredient in the complete telescope unit and is subject to numerous interfaces which will be the responsibility of the Gemini project office and other participants.

After listening to several project summaries and meeting with numerous active participants in telescope design, it is possible to think about a suitable scenario for arranging a transfer of activities. I would suggest that the following method might be a way to proceed:

i. Gemini Tucson project office must maintain a strong technical team for the mirror support and control for the duration of the design and construction program. Similar to ESO, they must have a core of technical experts, preferably 5 to 6 people full time, to insure that every aspect of the specification is met and also to monitor all interfaces with the telescope structure, controls, instrument mountings and cabling.

ii. The U.K. groups should organize themselves around a lead institution, possibly RAL, with other groups such as RGO, ROE, etc. acting as consultants to it.

iii. Gemini Tucson project office should prepare the basic performance specification for the mirror cell based on the engineering studies completed to date.

iv. In accordance with the specification RAL should submit a fixed price bid for the complete detail design, construction and testing of the system in the U.K.

v. Gemini Tucson should monitor all progress and technical developments and have the final say on all technical matters.

7. Summary

This meeting provided an excellent forum for reviewing the status of the various projects, as well as the degree of effort that each group has made in coming up with solutions for coping with seeing and wind buffeting of meniscus mirrors. ESO is confident that their design will meet the mirror seeing budget at least 99% of the time. They feel equally confident that their mirror support system can cope with wind buffeting, although they admit that more work is required on sensing wind loading.

Somewhat less optimism was expressed by the lone participant from the Subaru project on how their current design solutions would achieve performances consistent with their error budget.

Because the error budget tolerances in the two critical areas are a factor of 1.5 smaller for Gemini and Subaru, this means that some additional effort is required by these groups. For Gemini the solution for coping with wind loading is within grasp while the provisions for coping with mirror thermal control might require new technology and new techniques. Gemini has started to look into the possibility of controlling the mirror front face temperature by passing current through the coating. This investigation should be expanded with more research and practical tests. There may well be additional approaches that have so far been overlooked.

Walter Grundmann