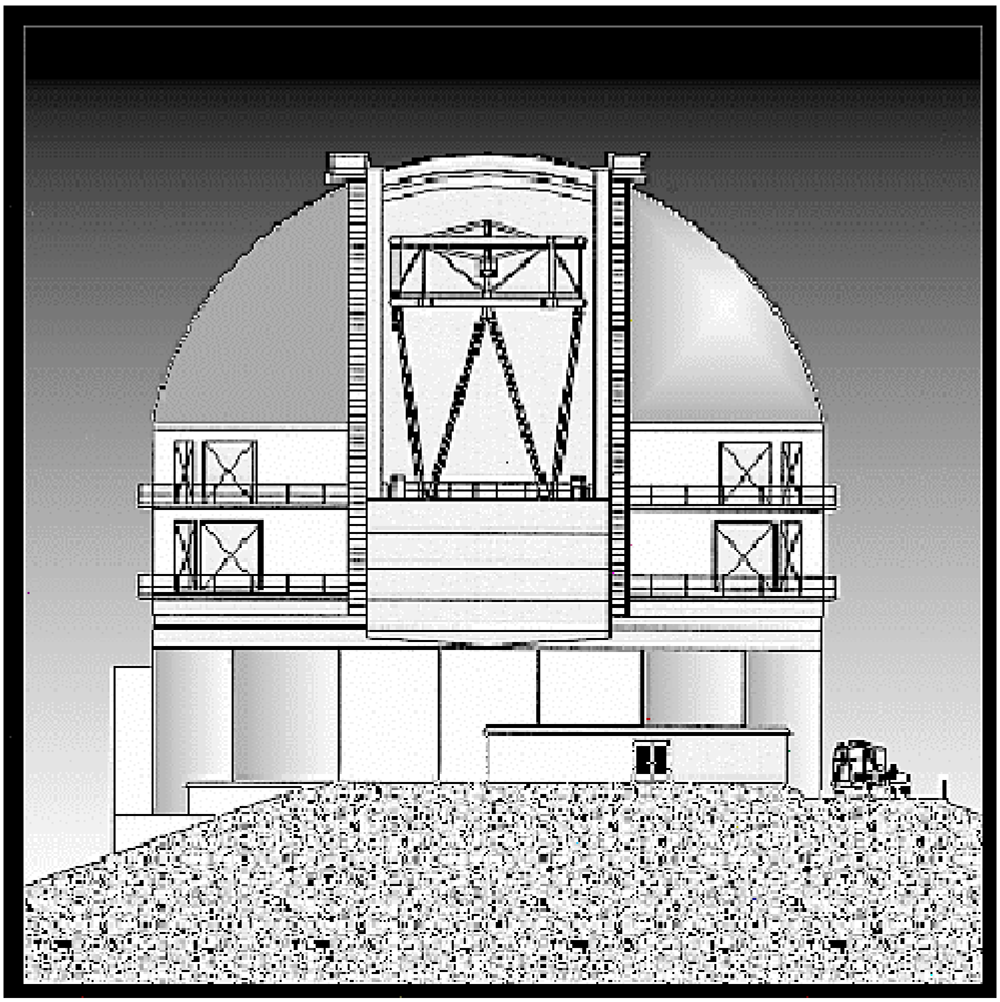
GEMINI
8-M Telescopes Project

REV-TE-G0068

Comments on the Telescope CDR



March 1-2, 1994

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Gemini 8-M Telescope Project
Telescope CDR
March I and 2,1994

Reference: Telescope CDR (Critical Design Review) Meeting held on March 1 and 2, 1994, in Tucson, Arizona.

Committee members participating in the review were: Anthony Abraham, Chair (KPNO), Walter Grundman (DAO), Donald Pettie (ROE), Dan Blanco, WIYN), and Peter Gillingham, (KECK).

GENERAL COMMENTS

(Comments by A. Abraham)

The telescope design has taken on a new look in a number of areas since the PDR. Many of the changes have been extensive and clearly reflect the development of the science requirements, engineering studies, and PDR recommendations. The broad range of new documentation prepared by the Project teams for the CDR is impressive and demonstrates the group's ability to be responsive and effective to the needs of the project.

There are still several mechanical designs in progress or under study which may be critical to the final design of the systems they interface with, e.g., secondary ring locks, primary mirror cleaning, and telescope ventilation. The interface requirements for these designs should be well defined before the fabrication contracts are'awarded for the mating assemblies.

The primary mirror cell, mirror support system, and other related details were not included in the review documentation but would have been helpful for determining if any assembly, operational, or maintenance problems might exist between the OSS review material and the mirror systems.

It is not clear how the various drive components are intended to interact with each other as a complete system, i.e., drives, brakes, preloads, interlocks, and hydrostatic bearing system. The component designs appear to be satisfactory but the system information would have been helpful for reviewing the individual designs. The entire system needs to be carefully reviewed.

The remaining design work, contractor support, site construction and erection work, and all the other project related activities will require the services of a highly qualified and dedicated engineering staff. They will be faced with difficult and challenging tasks in all the different roles they must play to bring the project together as a complete and successful system. The skills demonstrated by the current Project teams clearly show they have the capability to provide this support. Also, the proper level of technical staffing is critical to the success of this project, therefore staffing requirements need to be carefully planned for, reviewed on a regular basis, and supported in all areas to insure success.

(Comments by D. Blanco)

In general, I commend the Gemini Telescope working groups for an excellent job in the design, preparation and presentation of the complex design material.

Though I have some misgivings about revisions to the design since the PDR, I think the telescope is ready to go into detail design and fabrication. Since PDR the telescope has gained considerable weight, and consequently it has lower resonant frequencies and higher thermal inertia. I found the justification for these revisions - raising the primary mirror about 1/4 meter to improve flushing - less than convincing. The requirement of allowing up to thirteen tons of Cassegrain instruments is frankly astonishing. A system similar to that developed by Keck for exchanging large Cassegrain instruments (and secondary cage assemblies in their case) seems a more elegant solution. I suspect that there were other drivers for the changes that may not have been mentioned in the review.

(Comments by P. Gillingham)

I enjoyed the meetings; the presentations by the Project Office staff were carefully prepared and the speakers were very willing to explain and defend their design conclusions. As a newcomer to the review committee, I would have appreciated a little more introductory material; e.g., a list of the Project Office staff members who took part, together with their roles in the Office, also a list of Review Committee members and their aff i liations.

The amount of printed material provided two weeks in advance of the meeting (the 3 volumes of RPT-TE-GO01 8) 1 found daunting. 1. also felt that, during the review meeting, too much detail was presented on many of the topics, especially considering that we were given a full printed version of what was presented verbally. Stronger concentration on areas already identified by the Project team as problematic could have allowed more time for two way communication and elicited deeper discussion of the key issues.

I strongly support the view put by a number of the members of the Review Committee that it is important to have the project office adequately represented on site during erection and check-out of the telescope (and dome, of course). Preferably, some of the key individuals involved should continue with the telescope through and beyond its commissioning, to carry over the knowledge gained in design and erection to operation.

(Comments by W Grundman)

The telescope described at the CDR was considerably different to the design presented at the PDR in Dec. 1992. To some degree this is due to the PDR input, as suggestions were evaluated and the positive results incorporated in the design. There are also numerous design improvements that were initiated by the project team. However, the most fundamental changes to the design occurred in order to meet the self-imposed goal of "minimizing the amount of thermal mass located above the primary mirror".

A substantial amount of documents and reports were presented at this CDR, indicating that the project team had worked hard and diligently in order to meet the CDR deadline. Clearly some design solutions have not yet reached their optimum level of maturity, while others may have to be re-examined. To review this very comprehensive work fairly demands a good understanding of all technical aspects, and this takes time and dedication. The comments that follow are not necessarily based on the above, but at the least are based on a mixture of intuition and past experience.

(Comments by M. Morris)

My overall impression was that the design work on the telescope was progressing well and of a high standard; changes should now be limited to those absolutely necessary.

DESIGN COMMENTS AND RECOMMENDATIONS BY COMMITTEE MEMBERS

ALIGNMENT:

(Comments by A. Abraham)

The documentation contains a limited amount of information on how the mechanical alignment procedures will be done. Alignment will be a critical issue throughout many stages of the construction and installation of the telescope mount and the importance of this work cannot be over stressed. An inordinate amount of manpower will be consumed during site erection if this work is not carefully planned out at the front end of the project. The alignment work should not be entirely left up to the discretion of a contractor.

(Comments by P. Gillingham)

Reference was made to using the Cass rotator axis as the prime pointing datum; this seemed to be slightly misguided. Although it has the merit of being readily re-established physically, e.g., by mounting an alignment telescope on the Cassegrain rotator, the functional tolerance on the alignment and stability of this rotation axis (to control relative tilts of instrument and telescope focal surfaces or to keep infrared cold stops aligned with the telescope pupil) is much less critical than the tolerance desired for pointing purposes. It is by no means clear to me what would be the best way to define the prime datum axis, but I suggest more thought be given to this.

In the Keck case, numerous fiducial marks have been set up, e.g., around the interior of the center section, which can be viewed simultaneously by at least two electronic theodolites, to re-establish a three dimensional reference frame. In conjunction with a PC program to make least-squares fits to the observations, this has worked well, giving residual errors of typically 0.05 mm. The initial calibration of these fiducials and their relationship to other key features such as the primary mirror segment support points, was done by photo-grammetry, initially at the fabricators' works as part of the acceptance procedure then again after re-erection on site. In addition to adopting some such metrology system, I would advocate fifting a number of secondary alignment aids which allow quicker and more convenient checks, e.g., means of accurately re-installing cross wires.

(Comments by G. Herriot)

The committee felt that four people were not enough to oversee the telescope design, fabrication, alignment and installation. In particular, there is a need for a staff member familiar with alignment instrumentation and procedures. Simply subcontracting this important job will not work. (Tony, to be fair, I talked to Keith later, and it appears he put so little emphasis on alignment metrology in the CDR because he felt he had the problem well in hand. He had been working on Az. track alignment procedures for 8m telescopes while he was still back in the UK.)

AZIMUTH TRACK:

(Comments by A. Abraham)

Grouting: The dry pack grout under the track and the concrete surface on top of the pier should both be sloped away from the track to prevent oil puddling from spills. These surfaces should also be properly sealed to prevent oil from penetrating and weakening the grout and concrete.

(Comments by G. Herriot)

AZ track leveling. The final alignment before grouting was overlooked during the presentation.

(Comments by M. Morris)

I believe that any suggestion for the Azimuth Track to be split should be strongly resisted even if there is a cost saving. This would be more than offset by the cost of installation. A split track will never be as good as a single machined fabrication.

ALTITUDE DRIVES:

(Comments by A. Abraham)

The five bar flexure design is an interesting concept but may require some prototype development work to insure proof of concept. Due to the 1-2mm axial deflection of the drive disks it may be difficult to maintain the correct alignment and preload between the drive rollers and their respective drive disks. Every precaution should be taken to prevent overloading the drive disk under all driving and emergency conditions. Once brinneling, fretting, or scouring of the drive surface occurs repairs will be difficult and expensive to perform due to the way the discs are designed.

(Comments by G. Herriot)

Drives: The third generation of drive rollers, (simple cylinders, where prior designs had v-grooved or tapered rollers) finally looks right.

(Comments by W. Grundman)

For a change in telescope tube pointing from zenith to horizon the altitude disks spacing changes by about 1 mm. The five-bar flexure drive mount can accommodate this level of axial or radial run-out but it is not clear that it can accommodate the change in angular alignment associated with a 1 mm altitude disk spacing change especially since the drive rollers are now of the crowned-cylindrical roller style.

BRAKES:

(Comments by G. Herriot)

Brakes: More detailed analysis of the brakes is required. Especially under a loss of hydraulic pressure, how do the bearings and brakes interact? Which grabs first?

ENCODERS:

(Comments by D. Blanco)

I endorse the choice of lnductosyn encoders with the proviso that the electronic readout be improved from the standard issue. The lnductosyn system lends itself to absolute encoding by the addition of a coarse absolute encoder (such as a bar code reader) with resolution sufficient to identify the particular pitch of the lnductosyn tape. On start up the distance between the absolute fiducial marks is not known. The project might include a way of calibrating these fiducials by sighting on a precision polygonal mirror.

On other projects custom electronics have been necessary to successfully interpolate encoders in the face of the inevitable phase errors between the sine and cosine tracks. Slight departures from the nominal 90 degrees induce second harmonics (systematic errors that repeat at twice the tape pitch). These will confound the telescope tracking. We strongly recommend providing electronics which can accommodate phase errors.

ERROR BUDGET:

(Comments by M. Morris)

The error budget should be continually reviewed and the control system including the encoders, drives and servos should be the subject of a further review at some appropriate time.

HANDLING EQUIPMENT:

(Comments by A. Abraham)

Mirror and Top-End Carts: Due to the high cost of building and maintaining air bearing systems, alternate methods of transporting the loads should be investigated, e.g., tracks and trolley wheels.

Operating air bearing systems inside the enclosure also has the potential of stirring up a lot of unwanted dust.

(Comments by D. Blanco)

There was a plethora of handling equipment; platforms, cherry pickers and so forth for variousmaintenancetasks-mirrorwashingbaffletubehandiing,etc. Couldsomeof these be combined and streamlined? In particular you might consider a ladder on casters that can traverse across the face of the primary a few inches above the glass less dangerous than a cherry picker for mirror washing (cheaper too).

The use otair bearings to transport the mirror puts a severe constraint on the level of the dome floor with respect to the telescope azimuth platform. This proved particularly troublesome at WIYN where there the two floors are as much as 3/4 inch out of level. There should be some provision (jack screws or some such) for leveling the dome floor to the azimuth platform after telescope installation. Alternately, a bridge can be used to span the gap between the two floors and absorb some unevenness. Buckling of the dome floor during mirror removal can be reduced by providing a temporary brace to the pier.

The primary mirror removal trolley has been designed into a very tight space. The fact that its vertical travel is greater than its retracted height implies telescoping action, while it must also be horseshoe shaped to fit around the instrument rotator. Some of these constraints could be relieved by considering a hoist system that raises the mirror cell suspended by cable attached to lugs on the center section. This approach has the advantage of self aligning as well as providing greater stability and safety under seismic loading.

(Comments by W. Grundman)

The primary mirror handling cart is to glide on a system of air bearings while an associated guide rail is to aid in steering. My concern would be the nature of the interface between the rotating mount and the stationary floor. The air bearing will require a zero gap between the two, as well as a finite step variation in elevation. In practice I very much doubt that this can be achieved on the scale that is required here. Another problem with air bearings is the continuous air exhaust at floor level. With the dusty environment on Mauna Kea a lot of dust collects on the observing floor and to have this disturbed while transporting an unprotected new mirror, seems undesirable.

The illustrations of the primary mirror handling system show a very compact trolley, i.e., a large track gauge is not possible because of the inclined fork struts. This results in the trolley being highly unstable, particularly since the mirror mass, cell and bucket are concentrated at the top end. It is essential that the trolley be guided and restrained at all times and that this system meet all seismic activity requirements.

(Comments by G. Herriot)

The mirror cart will be top-heavy, and the guide track is too weak to prevent overturning in an earthquake.

(Comments by M. Morris)

I am not convinced that the air pads are the best solution for transporting the mirror and mirror cell. I would favour a well aligned low profile rail track.

CENTER SECTION:

(Comments by A. Abraham)

The documentation contains a considerable amount of detail on the construction and assembly procedures for mating the two halves of the structure. The bidding contractors should be encouraged to propose alternate solutions to these designs which could be more cost effective and possibly better.

The fabrication specification calls for heat treatment before final machining and prohibits welding after heat treating. One of the recommended assembly procedures calls for considerable welding at the adjoining surfaces after heat treatment; this procedure is in direct conflict with the specification. For the bests results the fabrication procedures should be accomplished in compliance with the current specification.

(Comments by W Grundman)

The center section is comprised of two unsymmetrical weldments which are to be bolted together on assembly. No explanation is given for the non-symmetry. If this has come about because of the attachment locations for the support frame, i.e., two attachment points at mid-span, then there are other ways of accommodating this attachment. Quasi-symmetry for the two weldments could be achieved by having one bolted joint to the left and the other to the right of mid-span.

BAFFLES:

(Comments by M. Morris)

The estimated weight of the baffles seems to be high at 250kg; this may be reduced by using a nomex honeycomb with epoxy glass composite on each side.

FACTORY CHECK-OUT:

(Comments by D. Blanco)

Factory assembly is a very good idea. The height of the required building can be reduced if the forward tube structure is removed or replaced with a temporary counterweight. This was done on the WIYN telescope to machine the elevation drive sectors in place.

(Comments by P. Gillingham)

In the case of Keck 1, an inordinate amount of time and trouble has been expended on the mountain-top in rectifying mechanical problems concerning, e.g., the attachment of instrument and optical modules. Much of this could have been avoided had there been appropriate functional testing at the maker's factory. The physical and especially the mental and psychological problems in doing demanding work at high altitude make thorough testing in advance of site erection even more important than is usual for a technically complicated project.

FOUNDATIONS:

(Comments by G. Herriot)

Pier / Soil / Telescope System Design: The low <3 Hz natural frequency is a product of a large mass, loosely suspended on a large lever arm. I am not sure that the project fully explored the trade-off between image quality obtained by putting the telescope at 20m above the ground to reach above the boundary layer versus the quality lost by the telescope and pier rocking on the soil. I wish that the telescope and pier could be made lighter, but we are locked into a design. The center ribs (at the middle of the pier) on the mat foundation are superfluous. The CDR design showed this area completely filled with concrete. In fact this whole area could be hollow or filled with cinders.

(Comments by P. Gillingham)

As with other studies of Mauna Kea as a telescope site, the resilience of the cinders is a problem, setting an undesirably low limit to the natural frequency of the pier. Was consideration given to the technique adopted by the Japanese for the Subaru telescope; making a very large, low strength but stiff raft using a mix of cement and native "soil"?

(Comments by W. Grundman)

Telescope response to dynamic excitation of the enclosure, i.e., wind buffeting, track transients, etc. could be minimized by avoiding a mat foundation for the enclosure. Should the possibility of using a piling foundation for the enclosure be revisited?

The foot of the telescope pier consists of a solid block of concrete that is 9 meters in diameter and 2 meters thick. It is not clear what purpose this amount of concrete serves and it should be investigated as to whether this central portion could not be made hollow as it is for the rest of the mat.

(Comments by M. Morris)

I think that the most worrying aspect of the over all design is the low modulus of the ground and also the possibility of coupling between the telescope and the enclosure foundations. Whilst the control system may be designed to cope with the wind buffeting it will not cope with the degradation of the track over a period of time; almost every track has suffered in some way through damage or fretting corrosion. The width of the aperture requires the telescope and enclosure to track together so the choice of steel, the alignment and the stresses must be chosen with care. Bogies too must also be appropriately designed. Maft's concern in 1 c and d of his memo to Keith dated 31/l/94 are real and should be addressed.

I discussed the ground modulus problem with ACER; they are the consultants to the JNLT. They implied that in their experience the first mode frequency was higher than those quoted in the Gemini report.

HYDROSTATIC BEARING SYSTEM:

(Comments by A. Abraham)

Oil Cooling:

Heat Exchanger: Two different design configurations are shown in the review documentation. One system shows high pressure cooling and the other low pressure cooling. Both systems will work satisfactorily but there are some tradeoffs.

Low Pressure Cooling: The heat exchanger cost is lower, there is less chance of oil getting into the glycol system due to leakage, and pressure losses are minimized.

High Pressure Cooling: High side cooling allows the oil at the pumps, filters, and accumulators to operate at temperatures more compatible with the system components, the heat exchanger can operate at higher temperatures, and the heat exchanger can more easily be located closer to the bearings.

Heat exchangers have been installed on the high pressure side at several older sites mainly due to system constraints already built into the equipment, i.e., pump types, equipment layouts, glycol and oil line access, etc.

Oil Troughs / Shields / Drains:

Altitude Bearings: The cover design looks good except for one minor recommendation. A small inspection plate should be provided in each upper cover to permit bearing inspections without removing the entire cover assembly.

Azimuth Bearings: Shield designs at each bearing do not appear to provide adequate protection from oil contamination to drives and encoding systems. Better shielding needs to be installed on the outboard side of bearings. A catch trough on the outer pier diameter, below the friction encoder, should also be considered for long term oil accumulation.

Oil spills due to plugged drains, air locks, etc. are always a potential threat. Both scavenging pumps and overflow switches should be included in the design.

(Comments by M. Morris)

The use of capillaries as flow dividers demands a high standard of oil purity and particular attention must be given to the removal of emulsified oil. Gear dividers and accumulators may be more tolerant of oil problems. All filters should be of the duplex type with automatic changeover.

The hydraulic bearings on the azimuth and altitude axis should be fitted as erection proceeds, the faces should be protected with a polymer sheet approximately the thickness of the oil film and removed on completion of assembly. There was much discussion about the paint finish.to the top end of the telescope but little on the affects the cables would have on the telescope performance. I would suggest that a carefully designed trunk is provided and that air cooling may be necessary to cope with losses in the cable system.

(Comments by G. Herriot)

Oil Stops: The primary mirror DOES extend lower than the altitude bearings even at modest zenith angles. Shields should drain into troughs, not over the outside. A simple *1* Omm gap between shield and trough is insufficiently labyrinthine to effectively contain oil.

SEEING EFFECTS:

(Comments by D. Blanco)

A general comment on telescope, dome and mirror seeing: The physics of these seeing sources is not well understood. While indicative, they should not be relied on for accurate quantitative results.

(Comments by P. Gillingham)

Seeing effects due to heat flow from tube and mount: The discussion of seeing degradation due to heat convected from the tube and mounting was, I believe, not soundly based in its leap from air temperature rise to seeing degradation. The referenced paper (Racine et al, PASP Vol 103 No. 667, Sept. 1991) reports CFHT observations which give a relationship between seeing degradation and ATd (temperature excess of dome air over outside air) and derives for the "seeing coefficient" 0.10+0.05 **arcSeC/o/C6/5 .** This has apparently led to the adoption of 0.1 5 as the coefficient for the Gemini s study (conservatively taking the upper limit from Racine et al).

From my own seeing studies at the AAT (SPIE Vol 444 pp 165-174, 1983), 1 derived a proportionality of about 0.5 arcsec/OC for the dependence on ATdand roughly 0.3 arcsec/OC for the dependence on ATm, the primary mirror temperature excess, when the primary mirror was unventilated. So I am slightly skeptical of the CFHT results, suspecting they may under-estimate the effect of a dome air temperature excess and over-estimate the effect of a mirror temperature excess (although the former may be affected considerably by the nature of the dome aperture and the ventilation, natural or forced through it).

In any case, the use of the CFHT relationship applying to ATd, toestimate the seeing effect of the temperature rise of air flowing from the tube steelwork'seems to me a misapplication, whatever the reliability of the CFHT data might be. I assume that using a relationship applying to the temperature excess of the dome air as a whole with respect to outside air overestimates the seeing degradation due to tube heat interchange. If the CFHT factor is too small, then the two errors tend to balance out, so I think the Gemini conclusion, that the effect of air heating due to the telescope steel work is within the error budget, may in any case be correct.

Of more concern to me is the suspicion that the decision to dispense with the Nasmyth foci may have been based on equally questionable arguments concerning seeing above the primary mirror.

INSULATION:

(Comments by D. Blanco)

I also recommend insulating the outside of the fork structure. The predicted contribution of this large mass of steel may have been underestimated and could dominate under some circumstances such as rapidly falling temperature. There must be new insulating materials to do this without introducing dust.

TOP-END LATCHES:

(Comments by A. Abraham)

The locks are buried inside the trusses making it impossible to work on them if a failure should occur when the top-end is installed. A simple fix can be incorporated by installing a manual quick release mechanism in each lock and by providing a small access port in the side of the trusses for installing a releasing tool.

(Comments by P. Gillingham)

The detail shown for the top-end to telescope attachments might be improved by having the male member part-spherical rather than conical, so it would have line contact, rather than an area contact, with the female cone. While this gives higher surface stresses, it makes the joint less susceptible to disturbance by foreign particles and less difficult to adjust into alignment. The AAT top-end joints are of this type, with hardened and ground stainless steel mating surfaces. They have performed flawlessly since 1974, with very good repetition accuracy.

The clamping screws in the AAT case are considerably more complicated in design than those shown for Gemini. The torque limiting clutches (which must, of course, have higher unciamping than clamping torque) were custom made. The screw is, if I remember correctly, driven with a mechanism which advances it through the appropriate pitch with each rotation prior to its engagement in the nut. There is some sprung axial travel to allow the screw thread to align with the nut thread. An additional set of such motorized clamping screws was made about 2 years ago for the new (2 degree field) AAT top end (Peter Gray, engineer in charge ' of the 2 degree field project at the time, and now at Steward Observatory) could comment further. I'm sure the AAO would be pleased to make the design details available.

(Comments by W Grundman)

The top end latching mechanism is completely buried inside the top tubes and is inaccessible for easy maintenance or servicing. Also, in the event of a component failure, while the top end is still engaged, the mechanism would be difficult to access. A more conventional design should be examined that has all major components easily accessible externally for maintenance and repair.

NASMYTH FOCI:

(Comments by D. Blanco)

The design has retained the Nasmyth platforms though it no longer has Nasmyth foci. The platforms should be reduced in size or eliminated. There is a balance here between allowing safe maintenance access and making access so easy that it becomes an attractive nuisance.

(Comments by P. Gillingham)

Abandonment of Nasmyth Foci: The decision to delete Nasmyth foci was, I gathered, irrevocable by the time of the CDR. It may have been the correct choice if provision of these foci was not consistent with meeting the very high optical performance goals set as the top science priority (due to compromising instrumental seeing). However, the arguments presented at this CDR relevant to this conclusion (the treatment of Seeing

degradation attributable to heat convected from the mount and tube) were not convincing - at least not in a quantitative sense.

Operationally, from my experience of using coude and Nasmyth foci, I rate very highly the merits of having a gravitationally fixed large volume in which an instrument can be set up reasonably independently of other telescope commitments and to which maintenance personnel have good access. I am, of course, well aware that a Nasmyth platform is by no means as stable vibrationally as one might wish and that providing

high thermal stability there is not simple. Even at coude foci there are advantages for the most critical work in vibration-isolation of the instrument support frame from the underlying pier,

PIER CONSTRUCTION:

(Comments by A. Abraham)

Cold Joint: The final pouring could be interlocked to the pier in the horizontal plane by chamfering or stepping the inner and outer edges of the pier at the cold joint. This change would require a simple modification to the slip form.

(Comments by M Morrls)

The top of the concrete pier should be adequately prepared before casting the top section. This should be done by exposing the aggregate with a pneumatic tool.

PRIMARY MIRROR COVER:

(Comments by A. Abraham)

The current design looks functional and easy to maintain. For optimum mirror protection the cover should be able to operate in any telescope attitude and should have an alternate or emergency method of operation. The drive chains are shown stowed in collection magazines which can sometimes cause tangling, a continuous chain arrangement may be a better design choice. Nefting is not necessary and will be short lived due to possible snagging or tearing during normal operations. If the hypothetical wrench should fall on the cover it would probably be better to trap it between the petals than to drag it to the edge of the OSS where it could fall on somebody or something.

(Comments by D. Blanco)

The mirror cover has a central cutout for the forward baffle tube. This precludes a complete seal over the primary, and appears to weaken the cover. This could be eliminated by designing the baffle as an interrupted tube as was done for WIYN. In this case such a design would promote the air flow over the primary. The accordion fold of the cover is shown oriented to open top and bottom, however this tends to collect dust and debris in the folds. Could the cover be rotated 900?

(Comments by W Grundman)

The orientation of the mirror cover panels, with respect to the mirror cell, should be changed by 90 degrees. These panels will be almost 1 0 meters long and would be easier to install if hung vertically from one end, instead of trying to insert them horizontally, as would be the case for the existing arrangement. By changing the orientation of the cover panels, any objects or debris nesting between panels could be removed by merely tilting the telescope tube and letting gravity do its job.

(Comments by G. Herriot)

Mirror Cover: Wires should also join the slats in the middle of their span to keep them from twisting under load.

(Comments by M. Morris)

The new mirror cover outline design looks to be satisfactory although I would use a material such as Kevlar for the mesh instead of nylon.

PRIMARY MIRROR CLEANING:

(Comments by G. Herriot)

Mirror Cleaning: Spending a full day on a cherry picker with a **C02** wand does not seem like a good way to clean a mirror.

PRIMARY MIRROR CELL ATTACHMENT: *(Comments by A. Abraham)*
The procedure for final attachment of the cell is not clearly defined in the documentation. If the last 1 0 mm of cell motion is to be done hydraulically through the attachment bolts it appears it will require an operator at each bolt working together to bring the assembly up uniformly or a single operator tightening each bolt a little at a time. Either procedure seems a bit awkward and it may be easier to consider a safer way to travel the final 10 mm with the trolley cart and then torque down the bolts.

(Comments by P. Gillingham)

The "Pilgrim" hydraulically preloaded screws (by Guest Keen and Nefflefold) with which I am familiar (as used for the primary mirror cell to Serrurier truss connections on the AAT) would not be capable of more than a fraction of the 6 mm hydraulic travel which was suggested would be employed in offering upthe mirror cell to its attachment points.

(Comments by G. Herriot)

Mirror Cell attachment bolts. The procedure for attaching the mirror cell requires 8 mm of travel on the hydraulic Pilgrim bolts. The committee was unaware of any with more than 2 mm travel.

MANUALS:

(Comments by G. Herriot)

Manuals. Maintenance manuals cannot be properly done in peoples'spare time, as was implied in the CDR.

HIGH RESOLUTION PIER LAB:

(Comments by G. Herriot)

High resolution laboratory in pier.

Light Shielding. Power and cable access should be light tight, since work will occur in the outer annulus of the basement. Stuffing old rags in the holes afterwards is inferior to planning in advance. The entrance should be level to allow dollying heavy equipment and should have double darkroom doors. The floor should be stiff and have very low hysteresis. Such HROS rooms take a long time to stabilize after a person leaves both because of thermal distortions, but also because the floor restores slowly after small deformations. Deflections of 1 00 microns are very apparent to stellar seismology experiments. Note that the CFHT Coude floor is reputed to work well.

RELIABILITY:

(Comments by G. Herriot)

How the telescope contributes to 98% the uptime (99% goal) was not addressed in the CDR. It is far easier to design for reliability than it is to retrofit a completed facility. The project should do both a top down and bottom up budget to see how far from reality the 98% is likely to be.

SCHEDULES:

(Comments by G. Herriot)

The proposed design and fabrication schedule is over-optimistic. While Coast Steel may have done Keck 11 in such a short time, they had Keck I as their preproduction prototype. The schedule needs specific tasks for rework/retest, as well as a separate item for contingency. The distinction is that there is a reasonable chance that you will not have to use the contingency. It is certain that there will be rework, and it should be shown explicitly.

SAFETY:

(Comments by A. Abraham)

(Section 13 Volume 1) Interlocks: Electrical switches are used in a number of applications to prevent the inadvertent operation of mechanisms during critical telescope operations. Electrical switches have a long history of unreliability due to a multitude of reasons and are not the best way to secure a system. All mechanical systems requiring special operating sequences for safety reasons should have manual lockouts, e.g, safety pins, stay bars, and tie downs.

Drive Protection: This section states that the oil system must be fully pressurized before telescope drives can be energized. If driving the telescope without adequate oil film thickness is the primary concern then uniform liftoff at all bearings is what is required rather than just monitoring oil pressure. Experience with these systems has shown that liftoff and full pressure do not always produce the same results. The best way to protect the drive system is to design the drive motor overload breakers to trip before the drive rollers can slip. This would protect the drive system against failures that could jam the telescope even if the bearing system was working flawlessly. Monitoring oil pressure will not offer protection to the drives under all operating conditions.

Brakes: Both telescope axis are using the brake system for stopping the telescope during normal operations and under emergency conditions (panic stop). Under normal usage it would be better to use the brake only as a holding clamp. When the drive motors are de-energized the telescope should be permitted to coast to a stop (time delay in brake circuit) then cycle the brake mechanism to clamp the structure in place. Even if oil pressure is lost the hydrodynamic effect of the bearings will bring the system down without damage to the bearings. Also, the proposed oil system uses an accumulator so oil pressure will be available to the bearings during coast down even if the pumps shutdown and the drives drop out.

(Comments by D. Blanco)

The interlock system is a suitable subject for a review all of its own. The system should be spare and simple and easy to diagnose. Interlocks have been known to cause lost time. I recommend the use of self lighting indicators for emergency stops, as well as a master control panel (or computer screen) to indicate status. Also recommend a procedure for disabling interlocks in a straightforward way. If this is not provided technicians will find devious ways to disable them. Overrides <u>should go in at the</u> same time as the interlocks themselves since active interlocks can be particularly troublesome during construction.

(Comments by G. Herriot)

FMECA -- Failure Modes and Effects Criticality Analysis. The interlock and safety systems appeared to be an afterthought which was not well thought out. For example section 13.3.9 is internally inconsistent between sections (a), (b) and (c).

Furthermore, the top end latches should only be energized by the locking pin at the horizon and not zenith. This distinction is not clearly described. I recommend that the motorized locking pin be also manually secured by a pin with a large flag.

(Comments by M. Morris)

The discussion on safety was useful and the Safety Committee has made a useful start to the Safety Policy document which should be eventually integrated with a full safety assessment carried out later in the design.

SEISMIC LOADING:

(Comments by W Grundman)

For the seismic loads analysis maximum stress levels of 43,600 psi are given for the azimuth radial and altitude guide pad brackets. This seems high for structural steel, but of even greater concern are the corresponding stresses in the bolting hardware. These are usually the items experiencing high stress levels and they should be designed to meet the emergency conditions.

(Comments by M. Morris)

The radial pad fasteners should be carefully designed to accommodate seismic loads. The Herschel has belville washers incorporated in the fastener. The use of these washers may be of use in the stops also, otherwise specially designed long bolts should be used.

TUBE TRUSS:

(Comments by W Grundman)

Without an attached top end the tube truss appears fragile and is unprotected.
Furthermore, misalignments between the tube ends and upper ends may be as much as 0.5mm, which are to be overcome by twisting the structures into alignment through the use of the latching mechanisms. With this approach top end alignment repeatability must be highly irregular. Should not the tube truss terminate with its own structural top ring? If this were incorporated, one could also provide a more kinematic style of top end connection that would guarantee alignment repeatability while avoiding high clamping forces.

(Comments by G. Herriot)

Top End Trusses Keeper: The committee felt that the upper end of the truss is very vulnerable to damage because it is quite flimsy with the top end ring removed. Some form of ring should remain, even with the top end removed. The latching mechanism should use a ball in a tapered hole instead of the proposed cone in a tapered hole which will j'am.

(Comments by D. Blanco)

On removing top ends the remaining tube structure appears fragile. Some light keeps or a permanent sub frame might help save the top end from accidental harm.

VENTILATION:

(Comments by D. Blanco)

I was puzzled by some details of the telescope ventilation system. There was some mention of retrofitting ventilation fans onto the azimuth platform if needed. Fans of the required size are best located at the exit end of a ventilation tunnel and not on the telescope. The ventilation paths through the telescope and pier need to be clear. In addition, locations for electronics boxes and cable ways should be identified and ventilation provided for these active heat sources.

I recommend installing ventilation holes in the forward tubes, arou ' nd the center section, drives and so forth during construction. It is much easier to cover these holes up if they are not needed than to add them in the field.

I recommend drawing air through the telescope fork, center section and tubes. Provisions should be made for the rotating seals across the elevation axis to complete these plenums. This was done for the WIYN telescope and was not difficult to incorporate into the design though retrofit would have been very difficult.

(Comments by G. Herriot)

Air Inlets at Top of Trusses: It is unclear how sufficient airflow may be admitted to the top end of the very light truss tubes, while still retaining their strength and also incorporating top end latches.

(Comments by W Grundman)

The tube truss and the upper end rings will also require thermal control by interior air flushing but no details were provided. With the change to substantially smaller structural tubes it may not be possible to provide adequate hole sizes for air exchanges as high as 1 00 volumes per hour, without seriously weakening the truss. Also, no information is provided on the routing of airflow in the main truss or on the airflow couplings between the center section and truss and upper end rings and truss.

TELESCOPE WEIGHT:

(Comments by W Gnindman)

Except for the main truss the telescope tube is very heavy. A 22 ton mirror is supported by a 50 ton cell, and 23 ton support frame (Bucket) and a 52 ton center section. Heavy box plate construction is a notoriously inefficient use of steel and its main purpose here appears to be to provide a massive counterweight in order to balance the tube since the elevation axis has been placed below the primary mirror pole. This large thermal mass is difficult to control and requires large air flushing, about 1 00 interior volume exchanges per hour, in order to meet performance specification. While this is planned for the center section, it is not at all clear that this is adequate, particularly for steel plate thicknesses greater than one inch. For now the support frame is without a thermal control system while the mirror cell will have some form of thermal control.

The other negative impact of such a heavy telescope mounting is that is reduces the eigenfrequencies of the complete structural system. The fact that the heavy telescope sits high on a pier, while the pier foundation rests on a soil with a low modulus of elasticity, makes for very low fundamental frequencies for the complete assembly, more typically associated with existing heavy equatorially mounted telescopes. For an alt-az mounting I would have preferred to see a significant improvement on this very fundamental characteristic.

The design is obviously too far advanced and the schedule too tight in order to make any significant changes to the telescope tube mass and so it will probably end up as the heaviest of the new 8 meter plus size telescopes.

It would have been helpful to have had a telescope weight summary right from the start. After reviewing report RPT-TE-GO01 8, one finally finds a weight summary on the last page. Furthermore, page 6-1 contains erroneous information, since it states that the primary mirror cell mass "has been allowed to increase from 43.000 kg to 48,000 kg (includes primary mirror support frame)..." The last page gives the mirror and cell weight as 70,300 kg.

CONTROL OF HIGHER FREQUENCY TRACKING ERRORS:

(Comments by P. Gillingham)
I have not attempted to calculate the availability of sufficiently bright stars to provide the 200 Hz bandwidth guiding signal said to be needed to keep the wind induced motion within the error budget. At the very least, this must reduce operational flexibility in requiring that a larger field be reachable by the guider.

I advocate very serious attention be given to the merits of inertially sensing as much of the relevant motion as possible. Optical gyros (both fiber gyros and laser gyros) are reaching performances which are very interesting in this regard. Insofar as much of the relevant oscillatory motion is, to first order, rigid body motion of the tube (i.e., the primary mirror/secondary mirror assembly) it can be sensed by such devices (or, over much of the relevant frequency range, by simple accelerometers). Compounding the signals from inertial sensors with those derived from a guide star and appropriately driving a fast steering secondary mirror is by no means a trivial problem, as was pointed out in the meeting. However, to rely entirely on the optical sensor seems to me to be neglecting a very powerful control possibility.