GEMINI PROJECT NEWSLETTER

THE GEMINI 8-METER TELESCOPES PROJECT works in conjunction with the Association of Universities for Research in Astronomy under a cooperative agreement with the National Science Foundation.

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# Gemini Director's Report

Very substantial progress has been made since the last Gemini newsletter went to press. As reported earlier, the preliminary design review (PDR) for the telescope mount was held in December, 1992. All issues raised at that review have now been evaluated and addressed. Design work is continuing, with the goal of completing the critical design review (CDR) in early 1994. The design of the enclosure has advanced rapidly, with the PDR occurring in May of this year.

Instrument planning is well advanced. Working groups from the partner countries are formulating specifications and evaluating options for obtaining instruments in a cost effective manner. The Controls Group is finally fully staffed, the software environment is being defined, and specifications for the various subsystems are being developed.

Memoranda of Understanding have now been signed that make commitments for the full $176M budgeted for the project. The partners in the project will be the United States (50 percent), the United Kingdom (25 percent), Canada (15 percent), Chile (5 percent), Argentina (2.5 percent), and Brazil (2.5 percent). The project team particularly wishes to welcome its three new partners and also to thank Goetz Oertel, the President of AURA, Bob Williams, the Director of CTIO, and Dick Malow, the Staff Director of the House Subcommittee on VA, HUD and Independent Agencies, for their efforts in bringing about the partnerships with Argentina, Brazil, and Chile.

A Memorandum of Understanding, which reserves the site between the Canada France Hawaii Telescope and the UH 88-inch telescope for the Gemini telescope, has been signed by the National Science Foundation and the University of Hawaii. The MOU guarantees that UH will receive 10 percent of the observing time on the northern Gemini telescope. The MOU also contains the following clause:

"In view of the recognized expertise of UH concerning instrumentation in the 1 to 5 micron region of *the spectrum, the NSF undertakes that the Gemini Partners* will assign to UH the work package for the 1 to 5 micron imager (including the associated focal plane array development) currently planned for the [northern Gemini telescope]. In the event this work package is substantially modified, UH and NSF shall mutually agree upon the work package which most closely resembles it for assignment to UH. Award of the work package shall be subject to final approval of the UH plan for this work package by an independent technical review to be arranged by NSF. UH will be entitled to compete for other work packages through normal U.S. channels. In return, UH will provide an agreed site within the Hilo University Park (hereinafter HUP) for the Gemini base facility, subject to the authorization of the UH Board of Regents, at a cost of $1.00 per year and will use its best efforts to meet Gemini requirements for a particular site. UH will also use its best efforts to secure funds from sources other than NSF, SERC and NRC for construction of a building in the HUP in which space will be made available rent free to the Gemini Project. The Gemini Project shall however be responsible for its share of operating expenses such as utilities, janitorial services, buildings and grounds

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upkeep and maintenance, etc. UH will consult with the Gemini Project on the design of this facility and will use its best efforts to be responsive to Gemini needs."

Progress on the project has been overshadowed by the controversy in the US concerning the choice of the primary mirror blanks. This controversy was intensified by the report of the Houck committee, which was a committee established to report to the US Congress on the status of the Gemini project. The goal of this committee was to address several questions that had been raised in the US community about such issues as whether the telescope design is consistent with the recommendations of the Astronomy and Astrophysics Survey Committee for an infrared-optimized telescope; whether it would be better to build only one telescope with US funds rather than two telescopes with international partners; and whether the cost estimates are reasonable and well justified. The members of the committee were Marc Davis, James Gunn, James Houck (chair), John Huchra, Gerry Neugebauer, Judith Pipher, and Stephen Strom.

The major conclusions of the committee are found in the responses to the seven questions contained in their charge:

***1. Are the scientific requirements for the telescopes as detailed in the Gemini Science Requirements Document responsive to the recommendations of the NRC Decade Survey for an infrared-optimized telescope capable of 0.1 arcsec imaging?***

Yes.

***2. Has the Gemini Project correctly translated the scientific requirements to performance specifications for the telescopes and their component sub- systems?***

Yes. However, at present less funding is identified for infrared instrumentation than for optical instrumentation. Most of the available instrumentation funds for the Hawaii telescope should be reserved for infrared instruments.

***3. Is the baseline Gemini design likely to perform to the specifications and provide a uniquely powerful imaging and infrared capability on Mauna Kea?***

No. In choosing a meniscus mirror over a honeycomb mirror, the Project has unnecessarily exposed itself to significant additional risk of failure. The decision traded a perceived short term financial risk in mirror blank fabrication for a long term technical risk to the telescope's performance. Although we did not find proof that the meniscus concept cannot meet the requirements, this approach is clearly more risky.

Based on the extensive material presented to us during the review, we conclude that is essential that the Project return to the honeycomb mirror concept. This is our principal technical finding. Previous NOAO/GEMINI committees have found the borosilicate mirror to be the preferred technical solution.

***4. Have compromises in the design that would seriously affect the infrared performance of the Mauna Kea telescope been made because of other demands on the telescopes?***

Not at present. The major compromise (aside from #3) was the decision to delay implementation of a silver coating facility needed for infrared optimization. The Project has now adopted this facility (or its functional equivalent) as a requirement.

***5. Is the cost estimate for the Gemini telescopes reasonable and well justified?***

Yes. The Committee examined the cost basis presented by the Project and did not find, in the limited time available, any evidence that the estimates were in error. However, the budget is very tightly constrained.

***6. What changes in design and/or instrumentation would be necessary to provide a single telescope— namely, an infrared optimized telescope on Mauna Kea —for $88M?***

N.A. It is unlikely that a single telescope satisfying the Bahcall Report recommendation could be built on Mauna Kea for this sum.

***7. Are the institutional arrangements between the U.S. and its partners appropriately responsive to U.S. scientific needs?***

Not yet in place. Although the Gemini Project does not provide for 100% of a single infrared-optimized telescope for U.S. astronomy as recommended by the Decade Report, the addition of international partners does enable the construction of an infrared-optimized telescope on Mauna Kea (see #6). We recommend that advantage be taken of U.S. facilities in Hawaii when locating the management operations center for the infrared telescope.

The Gemini Board devoted most of its February meeting to reviewing the recommendations of the Houck committee and determining how the project should respond to the report. The response of the Gemini Board was as follows:

"The Gemini Board welcomes the opportunity to comment upon the findings of the U.S. Gemini Review Committee, hereafter the Houck Committee. Because of a conflict of interest, Dr. Marcia Rieke did not take part in the discussion of the Report and is not a signatory of this response. Its responses to the findings of the Committee are as follows.

1. The Board welcomes with acclamation the strong endorsement given by the committee to the Gemini project, in particular to its scientific goals. Equally, the Board welcomes the strong endorsement of the international partnership to complete a very challenging project in a cost-effective and timely manner.

2. The Board reaffirms its determination to develop outstanding telescopes, instrumentation and associated facilities to serve the scientific aspirations of the scientific communities in the partner countries. It believes that, in reaching its preferred strategy for the construction of the two telescopes, it has succeeded in reconciling all the requirements of the communities involved, in particular, in constructing an infrared optimized telescope for the Mauna Kea site, entirely consistent with the recommendations of the Decade Review Committee.

3. The Board reaffirms its belief that the process which led to the choice of primary mirror in 1992 was carried out scrupulously by the project team. The board has the overall responsibility on behalf of the partner countries, not only for the scientific integrity of the project, but also for the management, engineering and operational aspects of the project. The international partners are operating within severely constrained budgets and the Board can confirm that, taking account of all these aspects, it has confidence in the recommendation made to it by the project, which it endorsed.

4. The Board welcomes the discussion of the issue of mirror choice and in particular the two aspects of the performance of the mirror and its mount which affect the ability of the telescope to obtain 0.1 arcsec angular resolution at infrared wavelengths, namely the effects of wind-buffeting and thermal mirror seeing. It recognizes that as yet there has not been a complete engineering study of the effects of the wind-buffeting problem. The results obtained so far by the project are encouraging but are in no sense complete in both areas.

5. The Board will take full account of the analysis of the Houck Committee and proposes a strategy which will incorporate their concerns and findings within the program of work of the Project. There is no question that a proper engineering study of the problem of wind-buffeting and thermal effects is essential and the results will be presented as part of the Preliminary Design Review in the Fall. If it is determined that the image specifications cannot be met with the meniscus, the Board will accept the borosilicate mirror for the Northern telescope provided its superiority is demonstrated."

On instructions from the NSF, which acts as executive agency for the Gemini partners, the project team is now proceeding with engineering design work in preparation for the PDR of the primary mirror assembly in November 1993. We are committed to a broad examination of the issues concerning the performance of meniscus mirrors, with special emphasis on the questions raised by the Houck committee. The written report of the Houck committee, which was prepared for non-specialists, provides little guidance as to the quantitative and technical rationale for the recommended change in mirror blank. In order to understand fully the nature of the committee's concerns, Matt Mountain and Fred Gillett have been working directly with the individual members of the committee. Jim Houck has also now been named as one of the US representatives to the Gemini Board, which will make the final decision on whether or not to proceed with meniscus mirrors.

Working with the Gemini Science Committee, the project will shortly set up a committee of senior scientists from the partner countries to amplify the science requirements document to specify more fully the performance of the primary mirror and to define quantitatively the environment in which it will be required to function. Members of the project team recently arranged a joint meeting with their counterparts in the ESO/VLT project and Subaru; team members also reviewed work on the support of meniscus mirrors already completed in the UK. The Gemini design is either consistent with the plans of the other groups or, in some specific areas, represents a significant advance on what has already been done. Commercial load cells and prototype actuators that meet the Gemini requirements already exist. Some of the issues relating to the support and thermal control of meniscus mirrors will be addressed in this and future newsletters.

The two critical issues for meniscus mirrors are support against wind buffeting and mirror seeing. Briefly, the Gemini design will succeed in supporting the mirror to the required levels of accuracy for winds at or below the 70 percentile wind speed on Mauna Kea, which is assumed to be reduced by a factor of at least two inside the dome. The 70 percentile limiting wind speed was established by the Gemini Science Committee in formulating the Gemini Science Requirements Document. In higher winds, image performance is compromised by such additional factors as the effects of wind buffeting on the secondary, and so the wind limits on the primary are consistent with limits on other aspects of the telescope structure.

Studies show that image quality is measurably degraded if the surface temperature of the primary mirror is higher than ambient by even as little as 0.5° C. Recent studies show much weaker dependence for temperatures 1-2° C below ambient. One strategy for controlling mirror seeing with a meniscus is therefore to condition the mirror during the day so that it is colder than the predicted nighttime temperature. To ensure we have additional margin in this area, Gemini will be investigating techniques to maintain the mirror surface nearer the ambient temprature.

The management of both wind buffeting and mirror seeing will be explored in quantitative detail at the time of the PDR. The PDR committee will be composed of people from outside the project with the requisite technical and scientific expertise. We will keep the communities of the partner countries informed of progress as we proceed with engineering studies during the next few months.

*— Sidney Wolff*
*Acting Project Director*

# An AURA Perspective

First: A cordial welcome to Chile, Argentina, and Brazil who have signed Memoranda of Understanding to join the Gemini project. We look forward to working with our colleagues in the Americas!

Gemini faces many issues and challenges as it gets on with the real job: to build outstanding telescopes in Hawaii and in Chile. To know the context helps understand the issues. Here are a few comments from the AURA perspective.

Gemini is an international project. It receives much attention because it is of vital importance to the science communities in all participating countries. AURA and NSF are both accustomed to serving the US community. In Gemini, they have another role: to serve several communities in an equitable way. That has not been hard most of the time because scientific interests and priorities, and opinions on the best technical approaches to meeting them, are remarkably similar among these communities. The recent controversy about Gemini's choice of primary mirror shows that opinions on how best to attain scientific and technical goals can differ — and what can happen if they do.

A look at Gemini's history is helpful. In the USA, the Science Advisor and the NSF called for international cooperation in major science projects. Congress established tough and firm requirements and deadlines that Gemini had to meet — including 50 percent foreign participation. The US is therefore implementing the first and third ground-based priorities of the Astronomy and Astrophysics Survey (Bahcall report) through international cooperation in Gemini. The UK, Canada, Chile, Argentina, Brazil all share in the costs and benefits of the project.

The international Gemini Board with representatives from the Gemini countries (50% US. 50% others) approves the budget for Gemini and sets broad policies. The Gemini Board named NSF as its Executive Agency. NSF in turn provides Gemini Board approved funds to AURA to carry out the project. AURA employees and Board members therefore do not serve on the Gemini Board.

The project can and does draw on the best talent and technologies of the member countries. It selects staff from among the best applicants from all countries. It awards contracts and work packages to agencies in member countries, in the best interest of the overall project. Sharing in costs is strictly proportional — sharing in intellectual benefits need not be in the same proportion.

NSF has contracted with AURA to build and ultimately operate the Gemini telescopes. In contrast to NOAO, where it serves the US community, AURA's job in Gemini is to serve six national science communities. Therefore, Gemini and NOAO — and the Space Telescope Science Institute — are separate units of AURA: NOAO does not "run" Gemini. Sidney Wolff, the Acting Gemini Director, will return to NOAO when the search for a permanent Gemini Director is complete. She is one of very few former NOAO employees who now work in Gemini.

Gemini works closely with national observatories in participating countries such as Dominion Astrophysical Observatory, Royal Observatories, and NOAO. Each has a point of contact, a "national Gemini office," as focus for working with the international project. NOAO has reorganized to strengthen its ability to represent US interest in Gemini.

Because Gemini is an international project, major decisions — including changes in direction with significant cost impact — require the active involvement of the international partners. Established as a US committee, independently of the NSF and AURA, the Houck committee reviewed Gemini and reported findings and recommendations from a US perspective. The international Gemini Board agreed with the Houck report in all respects but one: the recommendation to change mirror technology immediately. It decided to address the concerns of the Houck committee at the planned Preliminary Design Review (PDR) for the meniscus mirror and hold a PDR for borosilicate glass technology (BSG) if the meniscus fails to pass its PDR. Work on BSG before the PDR would be at the option and expense of the US.

Acting as Executive Agency for the international project, NSF adopted that position. So did Congressional staff that had asked for the Houck review. On April 16, 1993, the AURA Board adopted the following resolution after extensive review of the issue:

"RESOLVED, that the AURA Board of Directors endorses the decision of the Gemini Board to proceed with the design of the two Gemini telescopes based on the meniscus technology.

"FURTHER, the Board of Directors requests management to:

(a) continue to pursue and to seek closure to significant technical questions, including those raised by the Houck Committee;

(b) work with appropriate experts to ensure that the full capabilities of the astronomical community can be brought to bear;

(c) communicate these results to the U.S. community and the international partners; and

(d) prepare for a thorough and critical review at the preliminary design review (PDR) for the meniscus mirror.

"The Board of Directors supports requests for additional funds from the National Science Foundation (NSF) for development of contingency designs based upon borosilicate glass (BSG) mirror technology."

AURA will carry out Gemini accordingly. In addition, it will implement the US aspects of this resolution. That could include additional engineering work on BSG technology. Such work should seek two results: a detailed error budget and other data to help speed up a potential PDR on BSG mirror technology if it is needed; and studies that help projects that employ large BSG mirrors.

Finally, a word on people. Sidney Wolff leads the project team of scientists and engineers that is in turn led by Project Scientist Matt Mountain and Project Manager Larry Randall, respectively. The Gemini and AURA Boards provide oversight through a joint committee of both Boards, the Gemini Oversight Committee (GOC). The Gemini and AURA Boards each appoint three members and agree on the chair. Present members include Alec Boksenberg, Don Morton, Jerry Smith, and AURA Board members Malcolm Smith and Bob Szczarba. Bob Kirshner (AURA Board) is the first GOC chair. In April 1993, the AURA Board elected Frank Low and Joe Miller to terms that begin on July 1. The GOC may augment itself with up to two additional members by consensus. Finally, hosts are invited to GOC meetings: Bob McLaren from Hawaii and a Chilean to be named.

The Gemini Board now includes Bob Bless (Chair), Peter Conti, Ian Corbett, Jim Houck, Malcolm Longair, Don Morton, Wayne van Citters, and Gordon Walker as members. Chile will appoint one; Argentina and Brazil will alternate in providing one member. Bob McLaren represents Hawaii as host.

Many others from the Gemini communities participate on the science committee or on ad hoc and standing working groups within the project. Still others contribute thoughtful ideas, analyses, and recommendations. Many have been challenging, most have been valuable, all are valued.

People make organizations and projects work — not vice versa. I appreciate the interest and contributions from all. I am especially grateful to the project team for their enthusiasm and for their commitment to excellence and progress during good and hard times.

— ***Goetz Oertel***
*President, AURA*

# *Project Scientist's Outlook*

Large mirrors for large telescopes are difficult things to support. Since no mirror is perfectly stiff, the first thing you have to decide is how much distortion you can tolerate. Back in 1931, a French optician, Couder[1], determined that if you were building a diffraction-limited telescope, the mirror deformations should be no more than $\lambda/16$. Gemini is building two 8-meter telescopes that will approach the diffraction limit at 2.2 μm. This means that using Couder's criteria, these "deformations" should be less than 140 nm. In fact when you use the types of analysis available to the Gemini project in 1993, taking all the possible errors in a telescope into account, you conclude that the Gemini primary mirrors must not sag or bend anywhere over their 8-m diameter by more than an rms figure of 50-60 nm.

What approaches can you take to support mirrors to this accuracy? Simply using three points in classic laboratory fashion will not work, as can be seen from Couder's 1931 drawing **(Figure 1)**. Using a combination of analytical and experimental techniques, Couder established that any "glassy" telescope mirror for which the ratio of $(\text{Diameter})^4/(\text{thickness})^2 > 100$ (units in centimetres) these mirrors need a distributed support system.

Mirror support systems must accomplish two different tasks:

- Supporting the weight of the mirror at all orientations, with minimal deformation; and
- Defining the mirror's position and orientation in the telescope.

The distinction between these two tasks relates to the forces resisted. The mirror support deals with the force of gravity. The mirror defining system deals with telescope accelerations and externally applied forces, mainly wind and differential thermal expansion. Modern mirror support systems are also being asked to selectively deform the mirror to correct errors introduced by other factors, such as polishing errors or non-uniform temperature.

The design of the system to support the mirror's weight (choice of the number and location of support points) is principly determined by print-through considerations. The magnitude of print-through depends on the local stiffness of the mirror substrate and on the force applied (gravity). The local stiffness is relatively unrelated to global bending stiffness. Meniscus mirrors are very stiff on these small uncorrectable scales between supports, which is one of their inherent advantages. The required forces can be reduced by supporting the weight of the mirror on a large number of points — the best support has an infinite number of force application points (a continuous uniform pressure). However, a balance must be found between what print through can be tolerated and how many support points are needed because, as Couder wrote, "These devices ought to be constructed with great precision and, therefore, are rather costly. Besides, the adjustment of the whole system becomes much easier and more rapid when there are just a few of them. Therfore, it is of interest not to require more than necessary."[1] Still, all the new 8-m monolithic mirror support systems have to use a large number of active supports in order to meet their requisite image quality. Subaru, ESO-VLT and Columbus are all planning between 160-260 active supports for their primary mirrors;

the Gemini system requires 120 with air support — but has a total of 192 points where active forces can be applied.

How accurate do these active supports have to be? For Gemini we require that 80% of the light at 550 nm from the primary mirror system fall into 0.08 arcseconds. The Gemini support system will be making full use of the advantages of the meniscus approach. These mirrors have uniform thickness, hence uniform mass/unit area, and a uniform stiffness/unit area, so we can use simple air pressure to support 80% of the mirror weight without noticably changing the mirror figure. Consequently, the residual control forces only have to be accurate to 1 part in $10^3$ and have a dynamic range of ±500 Newtons, well within the capabilities of commercial load cells.

How successful can these support systems be? There is already an example of an a astonishingly successful polished meniscus from the Galileo Project shown in **Figure 2**. By concentrating on local smoothness and correcting any large scale errors with the active support system, the polishers produced a mirror that performs near the optical diffraction limit.

The important thing to realize is that effects of any force errors, during the polishing process, are directly related to the local stiffness of the mirror. As the local stiffness is really only a function of mirror thickness (to first order), and that the Galileo and Gemini meniscus mirors are both about 20cm thick, it is not unreasonable to expect that a polished 8-m meniscus could be supported and polished with equal success.

— ***Matt Mountain***
*Project Scientist*

Reference:

[1] M.A. Couder, from "Reserches Sur Les Déformations Des Grands Miroirs Employés Aux Observations Astronomiques", Bul. Astronomique, 1931, translated by Earl Pearson, 1966.

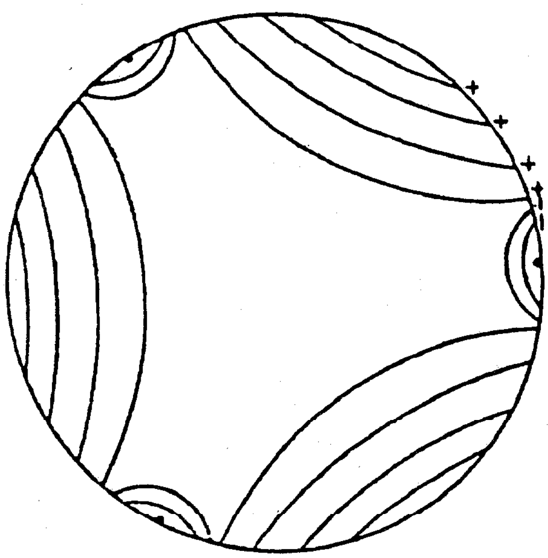

**Figure 1.** A sketch by Couder[1] of the deformations of a 23 cm diameter (3.25 cm thick) glass mirror supported by only three hard points.

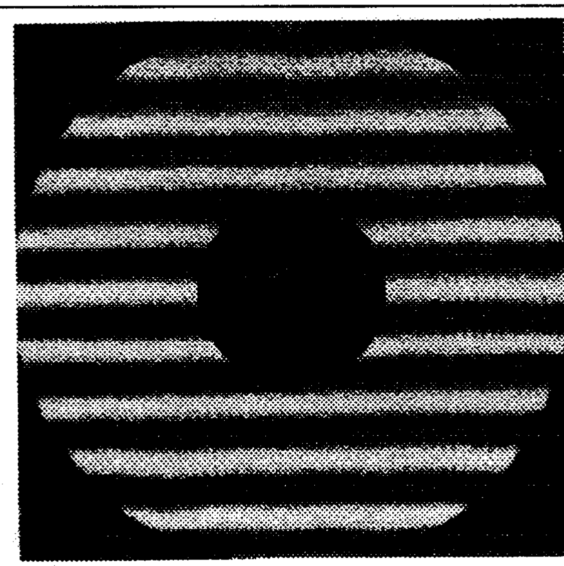

**Figure 2.** The interferogram of the finished Galileo 3.5 m meniscus mirror on its support system. The rms figure error is 8 nm. Taken from "Another Milestone in Modern Astronomy" by Knohl, Schillke and Schmidt, ESO Conference on Progress in Telescope and Instrumentation Technologies, April 1992.

## GEMINI GROUP UPDATES

# Telescope Structure, Building/Enclosure Group

The previous newsletter outlined the basic philosophy of the telescope design, including a description of how IR-optimization was achieved, while still incorporating a wide-field f/6 configuration and Nasmyth platforms. The enclosure design is based on an extensive analysis and evaluation program. This newsletter describes who is working on each of the technical issues and summarizes the progress made since the last newsletter.

### *Telescope Structure*

Since the telescope PDR in December work has proceeded in several areas:

- Peter Hatton has been developing the designs of the cable wraps and the primary mirror covers. The primary mirror covers present a particularly challenging design task due to the many stringent requirements for their operation. As a result, we are undertaking a detailed design of the primary mirror covers and are planning to build and test one of the sections of the primary mirror covers.

- Mark Warner continues to develop the telescope drive system. The altitude and azimuth drive motor mounts have been stiffened, and the geometry of the drive rollers modified to reduce contact stresses in the drive rollers. He has written a specification for the telescope hydrostatic bearing system and has updated the Telescope Design Requirements Document.

- The friction driven encoder test program, a collaboration between the Gemini, WIYN and Magellan telescope projects, involves testing two distinct forms of friction driven encoder (FDE) mounts. The first FDE mount, classified as a ground referenced FDE mount, has been designed and built by the WIYN project. With this design, the FDE mount is supported stiffly in all degrees of freedom (except radially). Testing of this FDE mount has been completed by Gordon Pentland and Mark Warner, with assistance from Rick McGonegal and Peregrine McGehee. The FDE mount was tested under a variety of conditions, including preload, steering angle, distance travelled and surface contamination. The second form of FDE mount design, the disk guided mount, operates under different principles. It is allowed to float on, and is guided by the drive disk itself. Gordon has designed a FDE mount, which was then manufactured by the Carnegie Institute as part of their contribution to the collaboration. The disk guided FDE mount has recently been mounted on the test rig at NOAO and testing will start after the enclosure PDR in May.

- Mike Sheehan has been working on the Finite Element Analysis of the telescope center section, the telescope drive mounts, the altitude drive disks and the primary mirror covers.

Westinghouse has completed their program on the design and testing of composite structures for the telescope trusses and secondary support vanes.

### *Enclosure Design*

On the design side:

- Steve Hardash and Gordon Pentland have been developing the design of the enclosure and support facility. We now have a completed concept design, showing layouts for the support facility (computer/control room, plant room, instrument preparation and storage, crew room, etc.), the coating facility, active and passive ventilation systems and the enclosure itself. Procedures for transferring the primary mirror from the telescope to the coating plant and for exchanging top-end rings have also been developed.

- Paul Gillett has completed a Finite Element Analysis of the enclosure structure under gravity, wind, crane and ice loading conditions.

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- Steve Hardash has completed the first draft of the design requirements documents for both the enclosure and the support buildings in preparation for the enclosure PDR on May 17.

On the performance evaluation of the enclosure:

- Steve Hardash has been involved with Ken Krohn (Contracts Administrator) in writing RFPs for the water tunnel tests. A contract has now been placed with the University of Washington and the first tests will start in April.

- Gordon Pentland has designed models for the telescope and enclosure water tunnel tests. A contract for manufacturing the models has been placed and the models were delivered for the water tunnel test program.

- Bob Ford has been refining the complex transient thermal model of the enclosure. The analysis models many effects, including: the enclosure and telescope thermal masses; convection between the enclosure/ telescope and the air; radiation to the sky from both the exterior skin and from within the enclosure; air infiltration during the daytime; active ventilation; variable wind velocity passing through the enclosure; solar heating during the daytime; actively ventilated enclosure floor; and active heat sources in the enclosure. The model will be used to predict the enclosure thermal performance and to develop the thermal control system. It will predict the power transfer to the ambient air and the temperature rise of the air as it passes through the enclosure under varying external conditions. These effects can then be related to seeing effects. The model is complete and has been calibrated against data available from the Keck and UKIRT domes.

- Dave De Young of NOAO has kindly undertaken an extensive program of computer numerical modelling of flow over the Mauna Kea and Cerro Pachon sites for the project using a Cray Computer at the San Diego Supercomputer Center. The first two phases of this program investigated flow over the Mauna Kea site and are now complete. Flow simulations were run with wind from the East and West directions at different velocities. As a result we have confidence in selecting the height of the telescope altitude axis above the ground level. The third phase of the program will be to investigate the flow over the summit of Cerro Pachon.

On site related issues:

- Paul Gillett has been working on many site issues for both Mauna Kea and Cerro Pachon. In addition to involvement in the Mauna Kea CDUA process, he has been involved in preparing for relocating the utilities that currently run across our site on Mauna Kea and developing the site layouts for both Mauna Kea and Cerro Pachon. He is currently developing a plan for the construction activity in Chile, including defining requirements for power lines, roads, and support facilities for La Serena and Cerro Pachon.

- Steve, Gordon and Paul have completed an update of the Conservation District Use Application (CDUA) Document. This document describes the Gemini project on Mauna Kea and has been submitted to the Institute for Astronomy (IFA) in Hawaii. After their review and approval, IFA will submit the application to the Department of Land and Natural resources (DLNR) in Hawaii. After review and approval by DLNR, a permit will be issued allowing the project access to the Mauna Kea site.

The enclosure design was formally presented to the Gemini Science Committee on March 25 in Victoria BC. Their comments will be provided to the enclosure PDR committee for consideration at the enclosure PDR in May.

### *Coating Plant and In-Situ Mirror Cleaning*

Work on the coating plant is slow as work cannot proceed until the agreement between SERC and AURA is finalized. However, a small work package investigating the effect of varying deposition parameters on the emissivity of sputtered aluminum has been completed by RGO under the direction of Brian Mack.

Ruth Kneale is coordinating a program at UKIRT to investigate emissivity degradation of aluminum coatings

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contaminated on Mauna Kea. Samples are being exposed to the environment for varying durations and the emissivities of the samples measured prior to exposure, after contamination and after cleaning either with $CO_2$ or with excimer lasers. This program will provide information on how frequently we will need to clean the Gemini primary mirror in-situ and which in-situ cleaning technique is the most effective.

— ***Keith Raybould***
*Telescope Structure, Building/Enclosure Manager*

# Optics Group

Since the start of the calendar year issues regarding the primary mirror have dominated the activities of the Optics Group. We put a lot of work into supporting the NSF Independent Review Committee investigation, and now we are working hard to prepare for the primary mirror assembly preliminary design review in November.

### *Primary Mirror Assembly*

Fabrication of high quality glass for the meniscus mirrors is proceeding on schedule at Corning's Canton, NY, plant. As of May 1, they have produced 27 boules of ULE™ glass that meet the Gemini specification, out of 84 required for the first mirror blank. Gemini personnel attended a quarterly review meeting at the Canton plant on March 17. At that time we saw the 8-meter rotating furnace that will be used to fuse the boules into a monolithic blank. Corning conducted a successful test firing of the furnace during the last half of March and the first half of April.

Early this year Eugene Huang and Myung Cho performed a series of studies relating to a new support system concept for the meniscus mirrors. The concept involves floating the mirror on an overconstrained hydraulic whiffle-tree system having six or possibly nine independent zones of support. Their studies of the six-zone system indicate a factor of four improvement in resistance to force errors and wind loads. Current design efforts are concentrating on developing improved mirror cell structural designs, with the hope that the concept may be extended to nine independent support zones in order to further improve resistance to wind and force errors.

As mentioned elsewhere in this newsletter, during the first week in March Gemini staff from Tucson attended the very productive joint meetings in Abingdon, UK and in Garching, Germany. Members of the Tucson, Canadian, and UK Gemini teams, Dr. Iye from the Subaru Project, and the technical staff of the ESO VLT Project exchanged information about the design of 8-meter mirror assemblies. This collaboration is proving to be very valuable for Gemini. We plan to meet again in August, but are keeping in touch in the interim by phone and email.

We have begun the process of setting up work packages for design of the primary mirror cell assembly, to be accomplished within the SERC institutions. Thanks to the cooperation of all parties involved, this process is moving forward smoothly and rapidly.

The Request for Proposal for polishing the primary mirrors has been completed and is currently in the approval process. The specification for the polished surface was prepared with help from a study by Breault Research Organization, of Tucson. This study is now included in the Gemini report series, listed in the back of this issue.

### *Secondary Mirror Assembly*

John Roberts, Eric Hansen, Larry Stepp and Fred Gillett visited three fabricators of silicon carbide mirror blanks in early March. We were greatly encouraged by what we saw. All three vendors are ready to submit fixed price quotations for fabrication of the Gemini 1-meter secondary mirror blanks, and all either have all the equipment they would need for the job in place or are only a few months of preparation away from having all the necessary equipment. One of these vendors is currently fabricating a silicon carbide mirror blank that is larger than the Gemini secondaries.

— ***Larry Stepp***
*Optics Manager*

## GEMINI GROUP UPDATES

# Controls Group

### *Controls Group Fully Staffed*

The Controls Group is now at full strength with the arrival of Steve Wampler as System Software Engineer and Mike Burns as Servo Control Engineer. Steve comes to us from Northern Arizona University where he was an associate professor in computer science in the College of Engineering. Steve has specialties in the areas of computer graphics, programming languages, operating systems, and systems programming as well as considerable experience through a number of industrial consulting positions. Mike comes from Honeywell Commercial Flight Systems where he was working on the control laws for a digital flight guidance computer. Prior to Honeywell Mike worked on missile seeker systems with General Dynamics.

### *System Design Review*

The complete focus of the Controls group is on a formal system design review scheduled for late September of 1993. The purpose of this review is the verification and validation of the standards, guidelines, plans, designs and work package descriptions proposed by the group - to ensure delivered systems that not only meet the Science Requirements but are also on budget and on schedule.

### *Documentation and Design*

In order to divide the Software and Controls work into manageable work packages that can be worked on in relative isolation a large effort has been expended in developing a plan that will effect this. This effort has resulted in the following documents, some of which are still in preliminary draft form or in progress:

- Software & Controls Management Plan
- Software & Controls Goals and Requirements
- Software Configuration Control Plan
- Software Programming Standards
- Electronic Design Standards
- Software Concept Specification
- Software Requirements Specification
- Interface Requirements Specification
- Design Requirements Specification

The end result of this effort will be a set of work package descriptions, which will be jointly written by the Controls Group and the developers of the individual work packages.

### *Visual Development and Control*

*(S. Wampler)*

The group is evaluating the use of the Khoros visual development system for two purposes within the Gemini Project:

- As a process control environment for telescope and instrument control.
- As a programming environment for the development of observing and system test programs.

The visual programming language Cantata provided as part of Khoros makes it easy to track operations, detect problems, and interrupt control flow for exception handing. It supports concurrent operation as well as distributed processing, and it is easy to tie into existing systems such as IRAF and ADAM for data reduction.

While Khoros is not intended for direct control in real-time, it supports near real-time well. We anticipate that true real-time would be achieved by running small modules controlling subsystems through an EPICS interface from within Khoros. The general approach is to develop small modules for subsystem control that can be used as program units within Cantata. This way, Khoros provides the connectivity, flow control, and sequencing, while the program units perform real-time control. This technique also permits the program units to function independently as well.

Khoros also provides a rich set of image and signal processing operations that might be useful for quick-look activities, though other systems are being considered for this as well. The newest version of Khoros, Version 2, features a data abstraction model that simplifies the use of Khoros with other data formats (with Version 1, all

## GEMINI GROUP UPDATES

data had to be converted to a Khoros-specific internal format, VIFF). Program units can be designed without worrying about the transport mechanism. Instead, Khoros assumes responsibility for providing the data transport between units (the transport may be via files, shared memory, sockets, etc.).

The capability to prepare programs visually is attractive as a tool for developing observing programs. Cantata provides Khoros with a full programming language that is visually oriented and extensible. Complex programming sequences may be grouped into procedures for both clarity and for later reuse. Visual programs can be compiled into script files for execution outside of Cantata.

### *Software Engineering Tools*

*(S.Wampler)*

The Controls group has obtained an evaluation copy of Cradle from 3SL (England). Cradle is a software engineering design tool based on the Release 2.0 of the Yourdan Structured Method with Ward and Mellor real-time extensions. Cradle claims to fully support the YSM (including life cycle stages, checking, etc.).

Over the next few weeks we will be examining Cradle for its suitability as a tool to help in Gemini software design and engineering. At this early date, it is not yet known whether any existing tool is suitable!

### *Epics and VxWorks*

*(P.McGehee)*

The setup and initial use of the VxWorks/EPICS encoder lab testbed was completed during the early part of this quarter. VxWorks by Wind River Systems, Inc. of Alameda, California is the real-time operating system proposed for the Gemini project and is in use at many international astronomical, research, and commercial sites, including NOAO.

The EPICS (Experimental Physics and Industrial Control System) which was originally developed by several U.S. National Laboratories for real-time control of large linear accelerator projects was installed on top of the VxWorks operating system and was first tested by developing a CCD Controller simulation.

To test EPICS more completely we converted the encoder lab testbed from PC to VxWorks control. This work consisted of defining database fields and operator screens with EPICS supplied graphical tools and writing two short C language modules (total length about five pages) to control the VMEbus based motor controller and to interface it to the EPICS real-time environment.

In March, a presentation of the EPICS system architecture was given by a representative of the Titan/Kinetic Systems industrial partner to the Gemini and NOAO Tucson staff. A formal demonstration of the VxWorks/EPICS encoder lab testbed is planned for mid-May.

### *PV-Wave*

*(P.McGehee)*

The other tool installed this quarter was the PV-Wave Visualization System available from Visual Numerics, Inc of Boulder, Colorado. The PV-Wave command language is based on IDL and provides extensive support of graphics, data analysis, image processing, data animation, GUI widget sets, SQL database access, and application development.

User written applications can be written in the PV-Wave command language as well as in the traditional FORTRAN and C programming languages. Near future plans for PV-Wave in the Tucson office include prototyping the A&G guide star catalog search and display system. PV-Wave can also be used to display real-time data through an interface provided as part of EPICS. We also intend to propose PV-Wave as the tool for on-line visualization and quality assessment.

### *Software & Controls Reports/Documents*

*(P.McGehee)*

PostScript and ASCII versions are generally made available via anonymous ftp. We stress that official copies of Gemini documents must be obtained from L.Friedman; those supplied here are in draft form. We make these available in order to keep our community informed, to promote discussion of the directions we are proposing, and to elicit criticism and corrections to these documents. If a Software

## GEMINI GROUP UPDATES

& Controls document you wish is not available or not in the format you need (the originals are in AmiPro) contact us to see if and when you can get it.

The ftp site is gemini.tuc.noao.edu, directory /pub/gemini. Contact: Peregrine M. McGehee (mcgehee@noao.edu)

### *Secondary Chopping Simulation*

*(M.Burns)*

A simulation of the chopping mechanism was done in order to baseline the type of servo system required and the amount of power needed to drive the chopper electronics. As expected the amount of power is critically dependent on the maximum frequency specified - currently 10 Hz. What was unexpected was the influence of the time constant associated with calculating the mirror velocity; the power increases if this time constant is significant with respect to the settling time. The tight settling band specification forces a fast controller which in turn requires both a fast estimator and an increased power — this settling band specification is not included in either simple electromechanical arguments or in naive scaling laws. This will be issued as a Gemini technical report in the near future.

### *Atmospheric Tip/tilt Correction*

*(M.Burns)*

A simulation of the secondary tip/tilt mechanism was carried out in order to baseline the servo system and to calculate the servo bandwidth and sampling frequencies required to meet the specification — currently stated as the removal of 90% of the atmospheric tip/tilt power. This simulation shows that the bandwidth is dependent on the model used for atmospheric tip/tilt power spectral density, and the sampling rate is driven by the number of delays and integrations in the sensor providing the error signal. For a Greenwood function, which has a sharp cutoff at a relatively low frequency, servo bandwidths of approximately 4 Hz will meet specification in the current simulation. For a modified Greenwood function, where there is a high frequency tail which falls off as $f^{-11/3}$, a servo bandwidth of 15 Hz is required to meet specification. If the sensor has 3 sample delays and 3 integrations then 1 KHz sampling is required. Once the sensor characteristics are known then a servo tuned for this should be able to reduce the sampling frequency required.

The next step in this simulation will be to include the effects of wind on the telescope structure and to recalculate the bandwidth and sampling rate required. Once completed this will be issued as a Gemini technical report.

### *Tracking Error Budget*

*(M.Burns)*

In a telescope system where active correction of the image centroid is possible, the use of the error budget becomes complicated. In order to allocate the error budget among the different subsystems, it is necessary to make assumptions about the power spectrum of the errors as well as their integrated power or rms value. By calculating the filtering effects of the different control systems it is then possible to use the power spectra for wind shake, atmospheric tip/tilt, and other disturbance inputs to reallocate the error budget among the different contributors. The basic problem is that it is not the integral of the disturbance source that is relevant, but the convolution of that disturbance input with the filtering function of the control systems. This work has just been started and will result in a Gemini technical report in the near future.

— ***Rick McGonegal***
*Controls Manager*

## GEMINI GROUP UPDATES

# Instrumentation Group

### *Goals for Gemini Instrumentation*

The Gemini goals for instrumentation are to obtain state of the art instruments with superior scientific performance, developed for the least cost, and with standardization and maintainability designed into the instruments.

The Gemini instrumentation philosophy is that an instrumentation program must exist from the beginning of the telescope development program. The instrumentation budget must not serve as a bank for other elements of the project to turn to when more money is needed, i.e. instrumentation is not the same as contingency. The telescope / instrument interfaces and their various interactions must be carefully studied and defined. Standardization of instrument components where possible and a sufficient level of high quality documentation are critical to effective instrumentation utilization and the overall reduction of operating costs. All of the above have an important impact on the overall program and should not be viewed as superfluous.

The instrumentation program must be structured in a way that fulfills the project's scientific goals, satisfies the intellectual requirements of the partner countries, and minimizes instrument construction, testing, and operational costs. The instrument work packages will be allocated based on each partner country's financial contribution to the project. After this "top-level" allocation, each of the national project offices, in conjunction with the Gemini Project Office will be responsible for the distribution of the allocated work packages within their respective country.

As a step towards achieving these goals, seven groups have been set up to advise the project on the requirements for instrumentation. The charge given to each of these groups is listed below.

- Develop the science requirements for a designated instrument or capability as input to the Gemini Instrumentation Plan.

- Determine, through discussion and consensus, the baseline functional requirements for each instrument and identify courses for future expansion of capabilities.

- Assist the Project in identifying potential instrument building groups.

- Advise the Project on how to obtain instruments with the required scientific capabilities at a cost the Project can afford without sacrificing performance, reliability or quality.

- Provide to the Gemini Project scientific and technical advice on specific instrument related issues throughout the design study phase.

Most of the working groups have met at least once and have also been discussing detailed issues using an e-mail conferencing facility set up by the Instrumentation Group. Their initial deliberations were presented at a meeting of the Gemini Science Committee in Victoria on 25th & 26th March. A summary describing the current recommendations for each group is given below.

We provide a synopsis of their recommendations to enable feedback from the larger scientific community. The summaries that follow are not a definitive recommendation from the groups but represent an insight into their current thinking. The GSC have fed back a number of suggestions and comments to the Working groups for them to consider in the next round of discussions. The next scheduled meetings are listed below, and an updated progress report will be presented to the GSC in July.

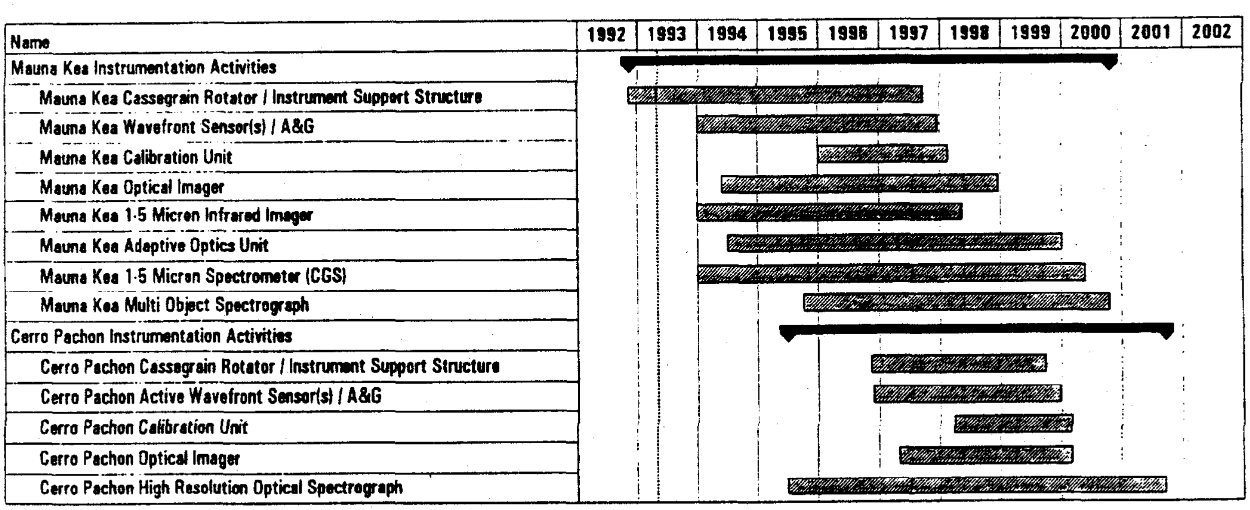
To give the community some idea of the present state of the instrument program, we include a preliminary instrumentation schedule which shows the phases of the instrument activities running from the design study phase to acceptance of the instruments at the telescopes.

***—David J. Robertson***
*Gemini Instrumentation Manager*

# GEMINI GROUP UPDATES

| Working Group | Next Meeting | Place |
|---|---|---|
| Adaptive Optics | Late May or *early June* | Tucson |
| Guiding and Active Wavefront Sensing | July 12 | RGO |
| High Resolution OUV Spectroscopy | TBD | Probably Tucson |
| IR Imaging and Arrays | ~July 23 | UCLA (IR Array Conference) |
| IR Spectroscopy | May 13, 14 | Royal Observatory, Edinburgh |
| OUV Multiple Object Spectroscopy | TBD | Probably Tucson |
| Visible Imaging, CCDs | Beginning of June | University of Hawaii |

## Preliminary Instrumentation Schedule



## GEMINI GROUP UPDATES

# Reports from the Instrument Working Groups

### Adaptive Optics Working Group

*R. Racine, Chair (U. Montreal), D. McCarthy (U. Arizona), R. Myers (U. Durham), S. Ridgway (NOAO), F. Roddier (U. Hawaii)*

The AO working group emphasized that adaptive optics play a key role in ensuring that the telescopes meet the Gemini Science Requirements and exploit the full potential of the telescopes for high angular resolution observations. Their survey of adaptive optics systems planned for major observatories further reinforced the belief that adaptive optics must be part of the initial telescope and instrumental capabilities for Gemini to be competitive. The group advised that in order to implement adaptive optics properly, the Gemini optics and other telescope systems and facilities must satisfy very rigorous requirements to provide the superlative performances that can be achieved from the superb conditions available at both Gemini sites.

The AO system recommended by the working group would be by-passable (in order to achieve the lowest emissivity at longer wavelengths where tip/tilt alone provides the performance gain) and would be able to be implemented in a progressively staged program. The design recommended by the group would have positions for two deformable mirrors in the system. A mirror conjugate to the mean turbulence altitude would be used for low order compensation ($n < 7$) and could be implemented first. A second mirror would be conjugate to the telescope pupil for higher-order correction. The group felt that this hybrid system approach has inherent flexibility from an observing perspective , i.e., it is "descopable" to lower orders when required. The group felt that this approach offers a modular and progressive development that can evolve as AO models, technology, experience, and the scientific requirements evolve and mature.

The group also recommended that provisions be made in the telescope design for launch of a laser beacon. With the system as described above, the system would evolve from lower to higher order correction with natural guide stars, and then to operation with laser guide stars. The group also felt that wavefront sensing should be available in the instrument to optimally match the AO to the science requirements for a particular instrument. Because the adaptive optics system has a strong degree of interaction with the active optics systems, which controls primary figure and telescope alignment, the group recommended that there be continual close consultation between the adaptive and active optics working groups. The need for image analysis methods to work with partially compensated images was also identified.

### IR Spectroscopy

*Pat Roche, Chair (Oxford), T. Davidge (DAO), J. Elias (CTIO), T. Geballe (JAC), P. Harvey (U. Texas)*

The working group recommended a 0.9-5 micron spectrometer with a resolution of from about 1,000 or 2,000 to 60,000. The pixel scales should be 0.05" and 0.15", with the instrument based on a 1024 X 1024 array detector. The slit would be greater than about 60" in length, and slit widths of 0.1" to 1" for the different pixel scales were recommended. The instrument should have an imaging mode for acquisition.

A 10/20 micron spectrometer/imager was also recommended. The operating wavelengths would be over the range 7-25 microns. The resolution would range from about 400 to 6,000. The pixel scale is 0.17" / pixel with a 256 X 256 array, with a provision for an upgrade using a 512 X 512 array. The slit width would be 0.35" to 2". The Michelle instrument proposed by ROE for Gemini was consistent with this configuration.

Other instrument options considered by the group as a lower priority were multiple object spectroscopy, cross dispersed spectroscopy, and imaging spectroscopy. The group felt that infrared spectroscopy instruments should have provision for wavefront sensing in the instrument and that the use of liquid cryogens, especially liquid helium, should be minimized or eliminated.

The group also identified the value of an adaptive secondary and the need for low dark current detectors (dark currents of order of 0.01 electrons/sec).

# GEMINI GROUP UPDATES

## IR Imaging

*J. Frogel, Chair (OSU), J. Graham (UC Berkeley), K. Hodapp (U. Hawaii), Neil Rowlands (U. Montreal), T. Soifer (CalTech), Phil Puxley (ROE)*

The infrared imaging working group report was presented by Phil Puxley of ROE. Phil presented the report as Jay Frogel had resigned (after the meeting) over the non-competitive award by NSF of the infrared imager to the University of Hawaii; two other US members resigned before the meeting (Tom Soifer and James Graham). Before his resignation, Jay led the working group in an effort to define the specifications of the imager.

The baseline array recommended was a 1024 X 1024, with pixels of 0.03", 0.07", and 0.2". The group did not want the design to preclude an upgrade to a 2048 X 2048 array although they felt that the effects of retaining this option on the optical design (and on the cost of the necessary optics) needed to be investigated. The operating wavelength of the instrument was specified at 0.9-5.0 microns, with a request for wavelength coverage to 5.5 microns. For spectroscopy and spectral line imaging, the group recommended 20-40 broad and narrow band filters, grisms with resolutions of 500 to 1,000, and space for a warm Fabry-Perot. The group did not recommend a cold Fabry-Perot. They recommended that the cold focal plane wheel have field stop (s), slits of various widths (for FOV's), and a coronagraph. The throughput goal is 45%, and a pupil imaging mode is desired for work at commissioning.

The group strongly recommended that the project should maintain control over the requirements laid down for the imager to be built by Hawaii. They also recommended that the imager should be subject to the same review processes as for all the other aspects of the instrumentation program.

The group did not set IR guiding as a requirement but did recommend that wavefront sensing be done with a cold dichroic either in or close to the instrument. The guide probes should not introduce additional infrared background and scattering to the instrument focal plane. For polarimetry, a wire grid and warm half-wave plate in front of the instrument was recommended. The use of cryogenic motors, the minimization of the use of liquid cryogens (no LHe, $LN_2$ for precool only where necessary), and the use of a standard array controller were generally endorsed.

***—Stephen M. Pompea***
*Gemini Instrumentation Group*

## Acquisition, Guiding, and Active Wavefront Sensing

*C. Jenkins, Chair (RGO), B. Woodgate (Goddard SFC), J. Beletic (Georgia Tech), P. Hickson (U. British Columbia), R. Laing (RGO)*

The various functions of the Gemini Acquisition, Guiding and Active Wavefront Sensing are considered as essentially services to the telescope and instruments. The model for the A&G and active WFS is based on the precept that there is sufficient commonality in the requirements for the instruments and telescope to consider these units as facility devices. It is unlikely that all the functions can be provided by a central physical unit but that they will be distributed around the focal plane area. A list of the proposed functions follows:

- Support one or more astronomical instruments with the entrance aperture fixed as rigidly as possible to the telescope focal plane
- Make available as many auxiliary foci as possible, in the interests of versatility.
- Enable acquisition to place objects quickly and reliably in a pre-defined position in the telescope focal plane.
- Provide a convenient way of both commissioning the telescope and monitoring its performance ( e.g. on- and off-axis tracking errors, building up pointing models, pointing tests.)
- Provide error signals from a tracking guide star (s), so that the servo loops involving the telescope, secondary mirror and instrument rotator can be closed.

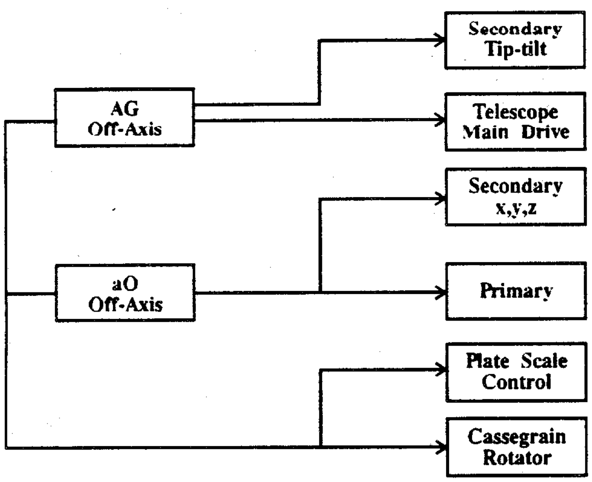
## GEMINI GROUP UPDATES

- Provide data on the incoming wavefront so that the primary mirror can be kept in shape and the telescope optimally collimated. This is termed active optics.

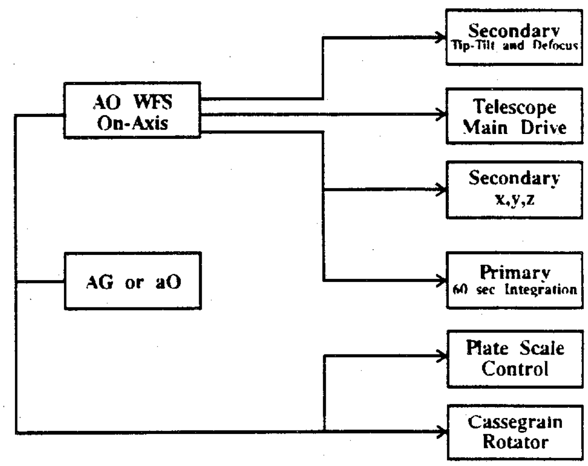
- Make available even illumination of the focal plane with calibration light. This illumination should mimic the telescope pupil accurately.

- Provide other common optical services, such as atmospheric dispersion compensation, polarization modulation or filters.

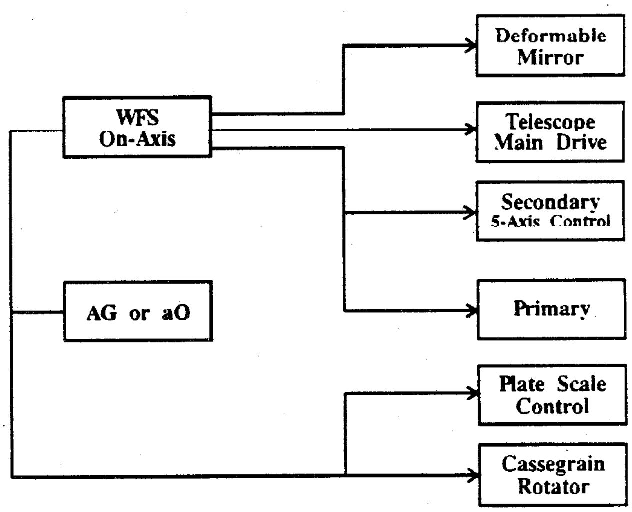
Shown below are three simple case models for A&G, active wavefront sensing (aO) and the proposed interaction with the adaptive optics system (AO).




**Case 1.** Not correcting for atmospheric effects, non-adaptive mode - outside of the isoplanatic patch.




**Case 2.** Tracking atmospheric tip/tilt and atmospheric or wind induced defocus using the AO wavefront sensor within the isoplanatic patch.




**Case 3.** Using the AO system for active and adaptive correction. Fast tip/tilt is provided by the deformable mirror with slow drift biases taken up with the secondary.

# GEMINI GROUP UPDATES

## CCD and Optical Imaging

*G. Luppino, Chair (U. Hawaii), T. Boroson (NOAO), J. Geary (CfA), J. Beletic (Georgia Tech), P. Hickson (U. British Columbia), M. Irwin (RGO)*

The CCD and Optical Imaging Group made the following recommendations:

***CCD's:*** Concern was expressed by a number of the group members that the CCD industry was very shaky at present with the possibility that current suppliers may get out of the business. Also there appears to be a problem in obtaining science grade devices with the larger format. The group recommended that the project consider a collaborative venture (with other large telescope projects) to ensure that a supply of science grade CCD's be readily available.

***Baffling:*** The use of baffles on both telescopes in optical configuration is considered essential and was therefore recommended.

***Corrector:*** To achieve the wide fields with telescope focal surface curvature of <2m will require a field corrector. The group recommended a study on the feasibility of building an f/16 field flattener with Atmospheric Dispersion Compensation.

***Mosaics:*** A great deal of discussion took place on the format for mosaiced cameras. It was considered that 4096 X 4096 CCD's would be readily available in the Gemini timescale through the development program. Therefore the group proposed that the baseline camera design should be 8K X 8K pixels, aiming toward a potential goal of 12K X 12K.

***Acquisition:*** A single 4K chip behind a 3:1 focal reducer is recommended.

***AO:*** It is recommended that a bare 4K chip be available at the focus of the AO system. This will yield a 100" field at high spatial resolution. A special AO detector CCD with a large format combined with a low noise, fast readout needs to be developed.

***HROS:*** A special skipper CCD or mosaic is needed for HROS.

## Wide Field Optical Spectroscopy

*P. Osmer, Chair (NOAO), D. Crampton (DAO), J. Allington-Smith (Oxford), J. Huchra (CfA), R. Schommer (CTIO)*

| | |
|---|---|
| Instruments: | Multi-aperture spectrometer for f/16 |
| | Multi-aperture spectrometer for f/6 |
| | Multi-fiber system at f/6 with 45' field. |

The group concentrated only on the first option.

***Science:*** Surveys of field and cluster galaxies, AGNs, and compact groups. Spatially resolved observations of velocity dispersions in extended objects. Spectroscopy of stars and unresolved objects, especially in crowded fields.

***Resolution:*** From R=200-500 up to R=5000 with 0.1" slit or R=5000 with 0.2" slit. Corresponding FOV are 2 and 8 arcmin, at pixel scales of .04 and .1" There is strong case for R up to 30K.

***Multi-object Capability:*** Multi-aperture laser or machine cut masks are preferred. Multi-slit (moveable) units are mentioned as operationally simpler but more difficult to make.

***AO:*** The minimum wavelength for AO mode is taken to be 0.5 μm for orders of correction now anticipated (4-5). AO determines the high spatial resolution field and pixel size. In the wide field mode only tip/tilt and active optics correction will be used.

***CCDs:*** A pixel size of 15 μm is assumed. The use of 4096 x 4096 CCDs or mosaics of 2048's is also anticipated. A double density (7.5 μm) may be desirable for high resolution mode.

***IR:*** There is a strong case for multi-object observations from 1 to 2 μm.

## GEMINI GROUP UPDATES

*Imaging:* This is needed to provide mask information in un-calibrated fields. This capability could replace the Optical Imager.

*ADC:* It was noted that atmospheric dispersion correction is essential due to the narrow slits.

The importance of baffling was noted, especially to eliminate ghost images of nearby bright stars. A flexure limit of 1 pixel shift over 0 to 75 degree zenith angles was stated. The requirements for acquisition and guidance were stated in general terms. It was recommended that the guide probes be integral with the instrument to minimize flexure. And it was recommended that the need for field and curvature correctors be investigated.

### High Resolution Optical Spectrometry

*C. Pilachowski Chair (NOAO), J. Landstreet (U. Western Ontario), M. Pettini (RGO), D. Walker (UCL), D. York (U. Chicago).*

*Resolution:* It was recommended that HROS be optimized at 100,000 with 0.33" slit. Available range of R should be 40K to 120K.

*Location:* As the likelihood of the funding for the Nasmyth optical train is small (total amount held against contingency) the group considered other possibilities. Cassegrain is considered acceptable if the flexural stability can be achieved. Floor mounted with fiber feed is recommended for the highest stability applications. It is recommended that further study of fiber fed systems be made.

*AO:* It is felt that only limited gains are available at wavelengths longer than 0.5μm and none at shorter wavelengths.

*CCDs:* No specific recommendations, but the pixel size should be small ( ~15 μm). Low noise read-out was emphasized, especially 'skipper' techniques. It was recommended that multiple detectors be investigated to allow integration of one spectrum while the last was read out.

*IR:* The group recognizes that the 1-2 μm region might be observable if an external focus were available. This will be recommended to the design team.

*Format:*

| | |
|---|---|
| Slit sampling: | at least 2.5 pixels at R = 100K |
| Minimum order separation | 8-10 " |
| Spectral coverage | Complete to Hα |
| Spectral coverage | 0.3 to 1.0μm |
| Slit length | 1 arcminute |
| Image slicers | TBD |

*Layout:*

| | |
|---|---|
| Collimator focal length | 2.8m |
| Collimator diameter | 175mm |
| Camera focal length | 1.0m |
| Camera diameter | 220mm |
| Monochromatic Focal Ratio | 4.7 |

—*William G. Weller*
*Gemini Instrumentation Group*

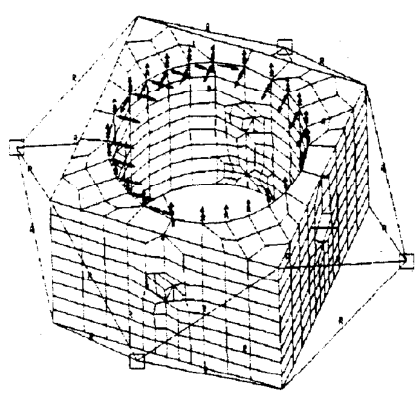
### Instrument Support Structure: Preliminary Finite Element Analysis

The instrument support structure concept consists of a cube, on the faces of which can be attached a selection of instruments. One of the faces acts as the interface to the mirror cell via the rotator bearing. The other five faces, one upward looking and four side looking ports are available for mounting instruments. The upward looking port is fed directly and is the lowest emissivity port position. The side looking ports are available for instrument mounting using an insertable fold mirror. The instruments in general may weigh up to 1000 Kg each. The largest instrument envisioned would be a Cassegrain-mounted high resolution optical spectrograph, which would weigh considerably more and could be mounted on the upwards looking port. The size of the box is determined by the back focal distance of the telescope (distance between the back of the mirror cell and the focus) and the need to have the focus fall some 300 mm beyond the instrument interface. The box is a cube with sides that are 1.6 meters and plays the role of a very stiff three dimensional optical bench. The analysis of this structure is described below but was done for a slightly larger, less stiff box. The results are indicative of the first order properties of such a box.

## GEMINI GROUP UPDATES

The rigidity of the mounting faces is very important as instrument alignment must be maintained under the changing gravity loads which will occur during altitude movements of the telescope and also with rotator operation in all but the zenith position. The rotator bearing also requires a flat rigid interface to avoid large changes in friction torque that can be caused by mount distortion. The concept for the structure consists of a cube with an internal cylinder. The cylinder and cube faces are joined by internal webbing.

**FEA Model of Instrument Support Structure**



An FEA model was constructed to model this structure. Lumped masses are attached to the box to represent loads due to instruments and the assembly is subjected to gravity loading. With this model the plate thickness of the mounting faces and webs can be altered to find an optimal mass for a given flexure. This optimization has not been completed as yet, but the current model achieves flexures of 20 microns zenith to horizon and instrument tilts of 97 microradians for a support structure mass of 4000 Kg and instrument payload of 800 Kg on each of the five faces. These errors can be compensated in the pointing/tracking model, have been folded into the error budgets for these functions, and are not considered to be significant. When the design of the box is developed further an improved FEA model will be constructed to give more accurate information and to optimize the structural performance.

*—David Montgomery*
*Gemini Instrument Group*

## A Collaboration with . . .

A collaboration is being developed with the U.S. Air Forces' Phillips Laboratory in Albuquerque for work in the area of modeling of adaptive and active optics systems. In this work with the Starfire Optical Range (SOR) at Phillips, the Gemini Project will receive assistance from SOR in complex modeling of adaptive and active optics systems. The results of the analysis done at Phillips will address a number of tradeoffs being discussed by the project and will have a fundamental impact on both the Mauna Kea telescope, where natural guide stars will be initially used in an AO system, and the Cerro Pachon telescope, where laser guide star use is a possibility. Some of the areas being modeled are:

- Curvature sensing vs Shack-Hartmann sensor
- Number of elements in wavefront sensor
- Control and sensing bandwidths
- Number of actuators and actuator density in deformable mirror
- Order of compensation
- Sky coverage issues
- Performance of laser beacon and natural guide star systems
- Position of deformable mirror in system
- Use of multiple deformable mirror systems
- Location of laser launch telescope

The efforts at Starfire are valuable aids to the project in formulating its AO plan for Gemini. The tremendous progress in laser guide star work in the past year is of great interest to the project, even though such a system for the Mauna Kea telescope is not in the current planning as laser beacons are prohibited on Mauna Kea. The project has received valuable input from the University of Chicago group, led by Dr. Ed Kibblewhite, which is installing a laser guide star system on the Apache Point 3.5 meter telescope. The project is also watching closely the progress made in experiments by the Steward Observatory group led by Dr. Roger Angel, at the MMT.

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The following technical reports have been published by the Gemini Project since the last edition of the Gemini Newsletter (February 1993). Copies of these publications are available on request by contacting the Gemini Project at the above address, Fax number or by E-mail (lfriedmn@noao.edu), attention: Linda Friedman, Documentation Coordinator. Specific report numbers are listed following the author(s) name in parenthesis.

### Technical Reports

4/12/93 — Gemini Enclosure, Support Facility & Site Plan Preliminary Design Review, R. Ford, P. Gillett et al. (RPT-TE-G0015)

4/30/93 — The Effect of Mirror Surface Figure Errors on the Point Spread Function of the Gemini Telescope, Gary L. Peterson, Breault Research Organization, (RPT-BRO-G0016)

1/22/93 — Report on Deformation of the Primary Mirror Cell and Its Effect on Mirror Figure Assuming the Use of an Over Constrained Axial Defining System, L. Stepp (TN-O-G0002)

2/22/93 — Effects on Surface Figure Due to Random Error in Support Actuator Forces for an 8M Primary Mirror, M. Cho, (TN-O-G0003)

12/20/92 — Optical Surface Figure Evaluation of an 8-m Primary Mirror, M. Cho (TN-O-G0004)

9/18/92 — Optimum Final Surface Configuration of an 8-m Meniscus Mirror Using First and Third Order Spherical Aberrations, M. Cho (TN-O-G0005)

4/12/93 — Chopping Secondary Control Study, M. Burns (TN-C-G0006)

4/8/93 — A Method for Determining Tip-Tilt Secondary Bandwidth and Power Requirements, M. Burns (TN-C-G0007)

**EDITOR'S NOTE:** In order to provide more timely Project information, the Gemini Newsletter will now be published quarterly: June, September, December and March.