GEMINI 8-M Telescopes Project

NEWSLETTER

June 1994 — Number 8

Gemini Project Overview

The four months since coming on board as Gemini Project Manager at the first of the year have been every bit as exciting as I expected. As I've become more familiar with the project, and especially with the people involved, my confidence has grown in the Gemini project team's ability to deliver the telescopes that the scientific communities of the partner countries want. I'd like to briefly highlight the project's accomplishments since the last newsletter and give my view of the current status of the project.

Telescope. We held the telescope structure critical design review in March. While making a number of minor design recommendations, the design review committee concurred with proceeding to select a contractor to complete the detailed design, fabricate, preassemble, and ship the telescope structures. We issued the request for proposals for that work in March.

Enclosure and Site Facilities. In May we awarded a contract to Coast Steel Fabricators Ltd. of Canada for design, fabrication, and installation of both enclosures. The State of Hawaii approved our application for a Conservation District Use Permit for Gemini North in April. Late in April we reviewed the final Mauna Kea site design prior to releasing the construction drawings for bid. Selection and startup of the site construction contractor is on the critical path of the Mauna Kea schedule.

Optics. The project has responded to all of the action items and recommendations from the primary mirror assembly preliminary design review held in December 1993. Corning is progressing very well with the primary mirror blank fabrication. Production of the ULE material for the first blank is complete and production for the second blank has started. In March we awarded the contract for polishing and transportation of the primary mirrors to REOSC Optique of France. The secondary mirror assembly conceptual design was reviewed in March and the request for proposals for design and fabrication of the secondary mirror chopping, tip/tilt, and fast focus mechanism will be issued in May.

Controls. In September 1993 the control system design review committee recommended development of a comprehensive top-level software design. The project passed the first major milestone in that process in April with review of the preliminary software design description.

Instrumentation. Work has started in the UK on acquisition and guiding preliminary design and in Canada on

TABLE OF CONTENTS

THE GEMINI 8-METER TELESCOPES PROJECT is managed by the Association of Universities for Research in Astronomy for the National Science Foundation under an international partnership agreement.

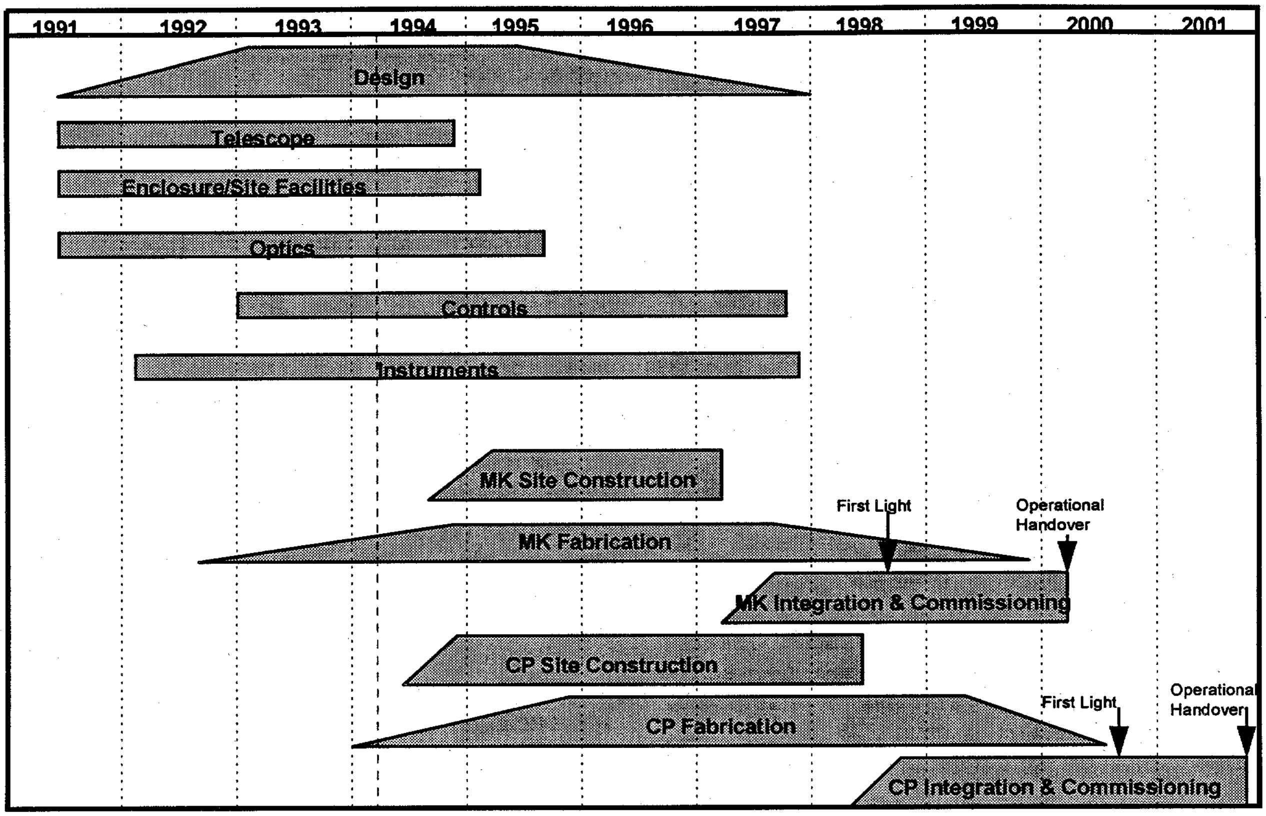


Figure 1. Gemini Project Schedule

adaptive optics concept definition. We will hold the preliminary design review of the Cassegrain instrument support in June. The Gemini Science Committee approved a plan for the initial Gemini instrumentation at its April meeting and the plan goes to the Gemini Board for approval in May.

Project Status. ***Figure 1*** shows the very top-level Gemini project schedule. At this point, we are about halfway through the design effort. With much of the design nearing completion, emphasis is shifting to construction and fabrication. During 1994-5 we will start all site construction and fabrication activities. Placing fixed price subawards (contracts or work packages) for this work on the planned schedule is the most critical project activity for the next year. Starting integration of the telescope systems at Mauna Kea and Cerro Pachon in 1997 and 1998, as shown on the schedule, depends on both timely commitment of the subawards and successful execution by the performers selected.

In order to make my own determination of the likelihood of completing the Gemini Project within the $176 million budget, my highest priority since starting as Gemini Project Manager has been to review the project budget and financial status. I have completed my review and I believe that the probability of completing the project within budget is high. Stated another way, I believe the probability of a significant overrun (>5%) is very low.

This conclusion is based on two factors. First, after careful review of the bases of their estimated costs-to-complete with the Gemini Group Managers, I found their estimates to be as accurate and realistic as possible. It is certainly possible to have honest differences of opinion about details of their estimates, but I do not believe there are any significant errors or omissions in their estimates. I also believe that the development risk in the project is very limited. For example, in the area of primary mirror fabrication, polishing, and transportation, regarded by many as one of the highest risks, we now have all of the work under contract with fully qualified firms at a total fixed price that is less than the original budget estimate plus contingency.

This brings me to the second factor underlying my conclusion - cost performance of the project to date. The $176 million project budget was originally established with two major categories: $114 million of fixed price subawards, which included a 10% contingency over the estimated cost, and $62 million for project operations, software, and instrumentation. This latter category included no contingency and was to be constrained to fall within the budgeted amount. The project's record to date in both categories has been very good. At this point in time we have negotiated fixed price contracts for 45% of the subawards, and we still have a 10% contingency available for the remainder of the subawards. Expenditures to date in the second category have been slightly under budget.

Looking ahead, the next 18 months are extremely important from the standpoint of both cost and schedule performance. By the end of 1994 we plan to have 80% of the fixed price subawards negotiated. This includes the construction contracts for the Mauna Kea and Cerro Pachon site facilities, which have relatively high cost risk due to the volatility of construction costs, especially in Hawaii. By mid-1995 we will have about 90% of the fixed price subawards committed and the remaining cost risk will be very low.

— Richard Kurz
Project Manager

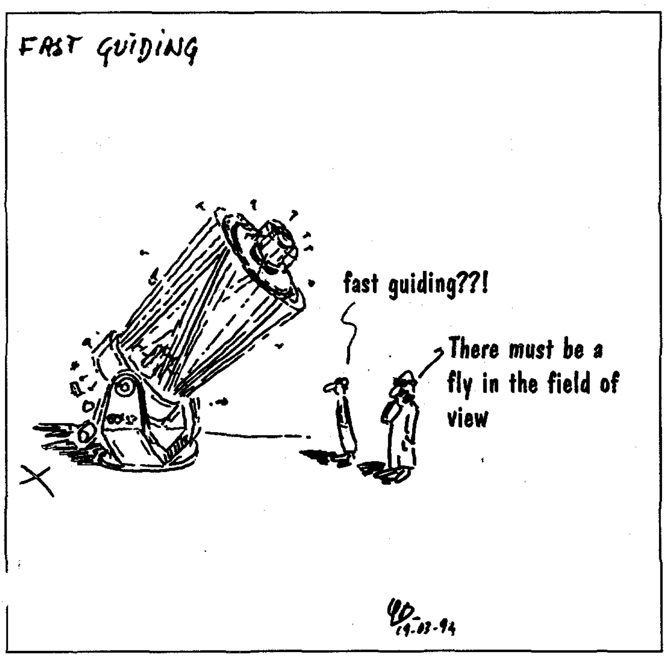
SPIE Symposium and 8-Meter Club Meeting

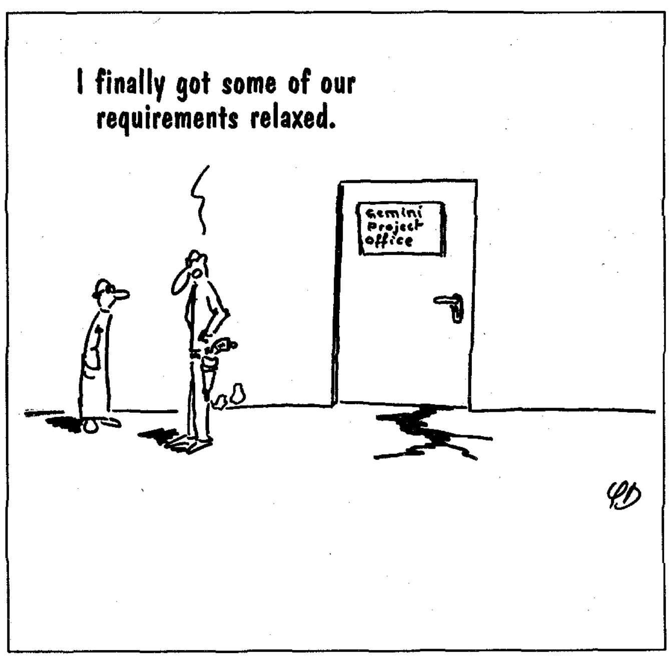
Gemini was well represented at the SPIE 1994 Symposium on *Astronomical Telescopes & Instrumentation for the 21st Century*, held at Kona, Hawaii, on March 13-18, 1994. A compendium of the 15 papers presented by the project is available as document RPT-PS-G0029. These papers constitute a good technical summary of the Gemini design.

Following the conference, the 8-Meter Club met on March 19, 1994, with strong representation from the Subaru, VLT, and Gemini teams. The projects interchanged very useful information on the following topics:

- Local seeing effects
- Seismic modeling and earthquake safety
- Telescope alignment
- Acquisition and guiding
- Wavefront sensing
- Primary mirror coating removal

The cartoons provided by ESO and reproduced here were far and away the most popular summary of the proceedings.





Project Scientist's OUTLOOK

The New Gemini Instrumentation Program

Trying to envision what instruments will be used on Gemini at the turn of this century can be a tricky undertaking. Of course this is exactly what we have been trying to do for the last year within the Gemini Partnership. So what approach have we been taking?

Consider the following problems. The stars in ***Figure 2*** mark a recent set of temperature-luminosity determinations for a series of low luminosity red dwarf stars taken from Jones, et al. (1994). As can be seen, these stars are moving intriguingly down recent model calculations towards that critical point when the mass of the star is so low it can no longer support hydrogen burning.

The lowest luminosity star, GD 165B has a calculated mass in the range 0.067 - 0.089 solar luminosities (depending on the assumed age) so may no longer be a star but could be a brown dwarf with a temperature as low as 1800 K. However to confirm this we will need more accurate data and equally important, additional measurements of similarly cool objects. The rich spectra which enabled such detailed agreement with these models is shown in ***Figure 3***.

As can be seen, the problem of course is that as the dwarfs get less luminous, they get fainter compared to the sky, and consequently the spectra get far noisier. These spectra were taken with a high throughput spectrometer using a 3-arcsecond slit on a 4m class telescope (UKIRT) on Mauna Kea. GD 165B has a 2.2-micron K magnitude of 14. How much fainter could we get repeating this experiment on Gemini?

As these dwarfs are point sources, on Gemini it will be possible to use 0.1 arcsecond slits (see Ellerbroek at al. 1994). So the collecting area will increase by $(8/3.8)^2$ and the sky noise will decrease by (8/3.8) (0.1/3), the square

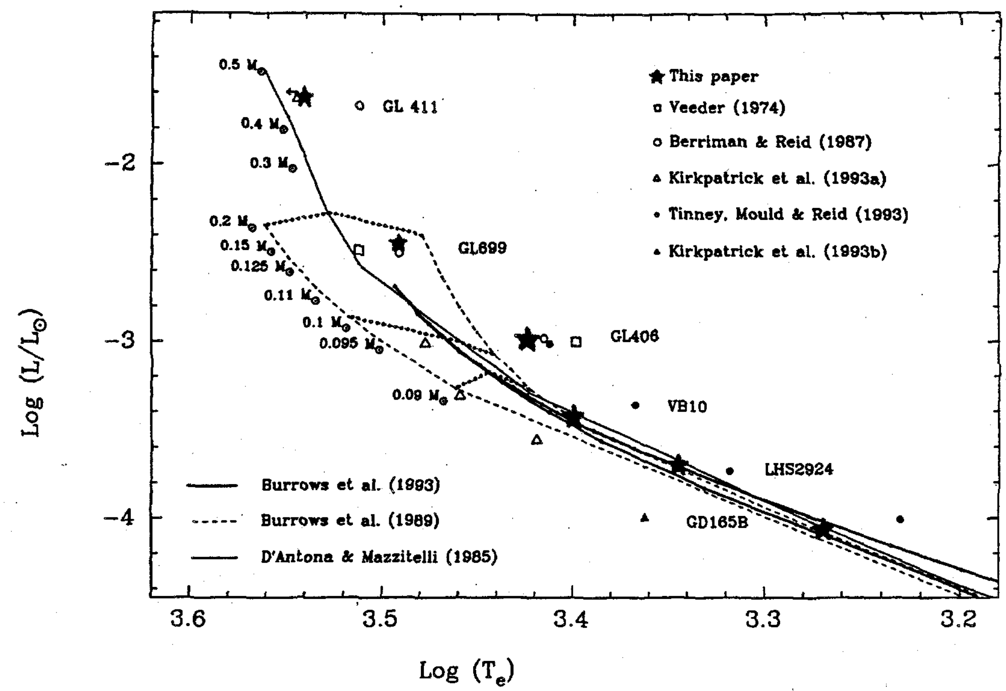


Figure 2. An infrared sequence of brown dwarfs?

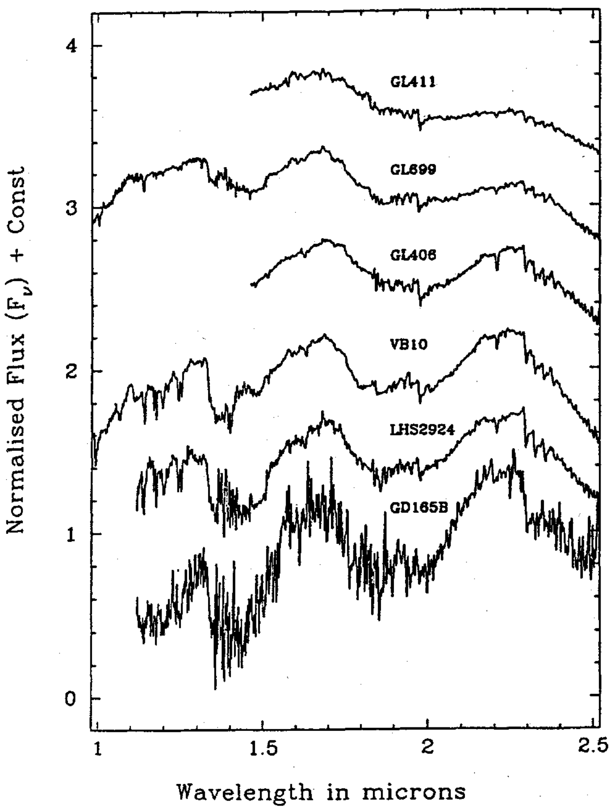


Figure 3. An infrared sequence for M dwarfs

root of the sky background change in going from 3 arcseconds slits on UKIRT to 0.1 arcsecond slits on Gemini. Recent shift-and-add results from the IRTF and UKIRT are showing it is already possible to get 20-30% of the 2.2-micron flux from a point source within 0.12 arcsecond (see the article by Terry Lee - this edition and Shure, et al., 1944, Puxley, et al., 1994). In addition, the new 1024 x 1024 arrays would allow the complete 1-2.5 micron spectra to be taken in a single exposure; the UKIRT spectra had to be taken as six independent exposures. Consequently, making some allowances for slit losses (Ellerbroek, et al., 1994), a Gemini IR spectrograph could repeat the same set of observations shown in Figure 3 on dwarfs as faint as magnitude 18-19. Another way to look at this is that a similarly luminous sample could be measured throughout a volume of space, within the solar vicinity, almost 200 times larger than currently possible with 4m telescopes.

It will not just be at infrared wavelengths that new science will be possible by exploiting the background limited sensitivities of Gemini. ***Figure 4*** shows a cluster of galaxies imaged with the HST in the R band (before its refurbishment) compared to a ground based image of the same region taken in ~1 arcsecond seeing. Alan Dressler, whose image this is (Dressler, et al., 1994), believes he may have discovered a "nascent cluster of galaxies at redshift z ~ 2". The only reliable way of determining the redshift and gain some insight into the nature of these possible early epoch objects is to measure their spectra. However as these galaxies have R magnitudes ~ 22-24, this will be a fairly challenging undertaking on 4m telescopes. Not only will sub-arcsecond slits be required to distinguish and isolate individual objects, but also to reduce the sky contribution to keep the spectra from becoming completely swamped by sky background noise. In ***Table 1*** Davidge (1994) has calculated the signal/noise that might be expected from observing these objects for three hours with Gemini using adaptive optics for slits varying from 1 to 0.15 arcseconds.

As can be seen, resolving the nature of these galaxies or other intriguing objects that the newly refurbished HST will turn up may have to wait until we can get sub-arcsecond spectrographs (or integral field spectrographs, see the article on this approach by Simon Lilly - this edition) on the new generation of 8-10m class telescopes.

The basic principle behind these expected large gains in signal-to-noise of the new large telescopes compared to our 4m class telescopes is that in the background limited regime,

Signal/Noise α Telescope Diameter (D) / Image Diameter (θ)

or

Signal/Noise α D^2 for diffraction limited observations

It is in the infrared where this can be seen most dramatically. Not only are the backgrounds large, but at these wavelengths the atmosphere is particularly cooperative in that simple tip/tilt compensation and low order adaptive

Adaptive Optics Order of Correction	Slit Width at 800nm 1.0	0.5	0.25	0.15
n=1	2.5	2.7	1.9	1.3
n=5	2.7	3.2	2.9	2.5
n=10	2.9	4.2	5.6	5.9

— Gemini AO System

S/N ratios in good seeing after 3 hours integration with Gemini on R = 22 magnitude galaxies

Table 1. The results from recent modelling of the expected signal/noise ratios at 800nm using a multi-object spectrograph on Gemini to observe the Dressler galaxies.

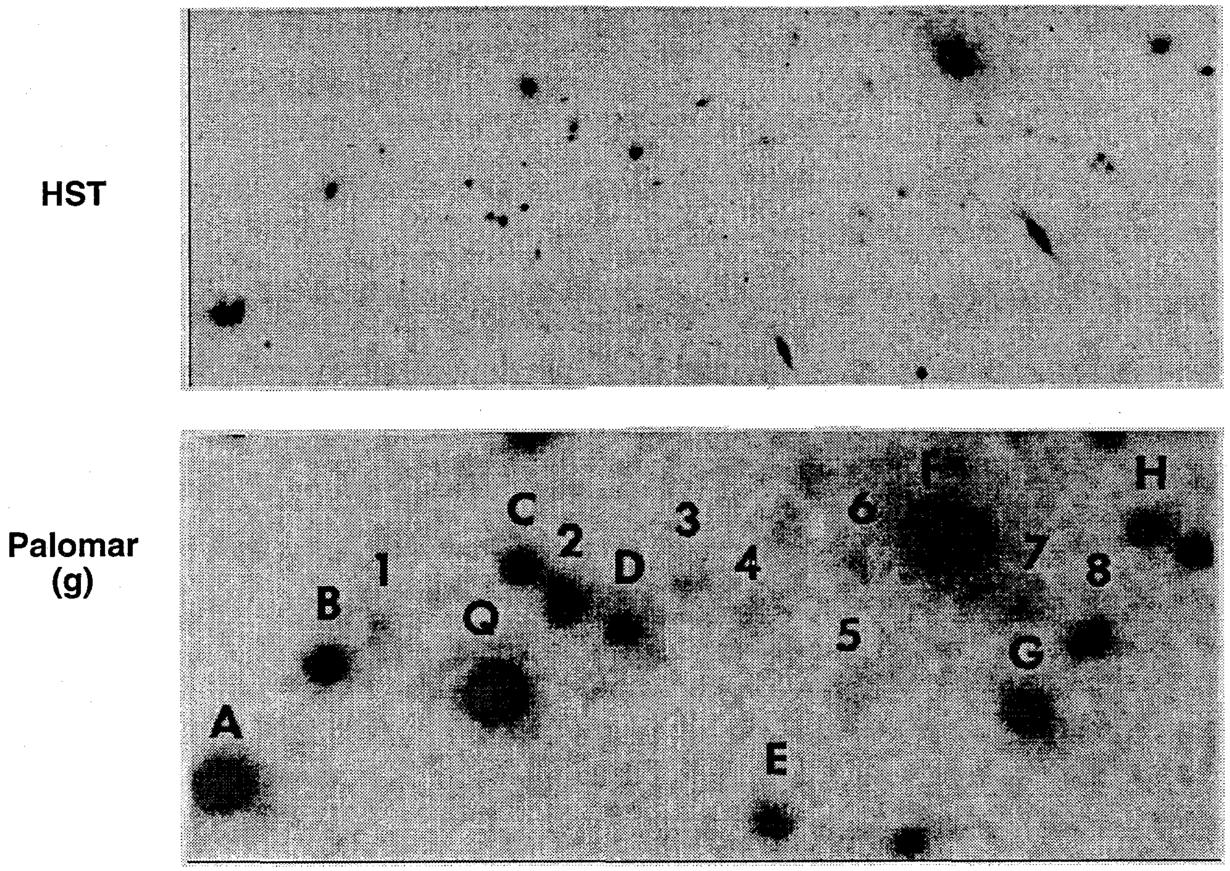


Figure 4. A nascent cluster of galaxies at z = 2?

optics can produce large improvements in delivered image quality. This effect can be seen in ***Figure 5*** which plots the expected 1 sigma 500 second point source sensitivity of Gemini as a function of IR wavelength. The rectangular boxes which mark the Gemini sensitivities are bounded at the upper edge by image quality expected with simple tip/tilt corrections, and at the lower (more sensitive) edge by what would be expected with diffraction limited performance in good seeing conditions.

The other part of observational parameter space where large gains can be made with large telescopes is when the detector system is the limiting noise source. The signal/noise ratio then becomes proportional to the collecting area of the telescope or

Signal/Noise α D^2 for detector noise limited observations.

A graphic illustration of this effect can be found in the possible measurement of a primordial Deuterium/Hydrogen ratio at z ~ 3 of 2.5 x 10^{-4} made by Carswell, et al. (1994) on the KPNO 4m, was also observed at dramatically higher signal/noise (87 as opposed to ~10) by the High Resolution Spectrograph (HiRes) on the 10m Keck telescope (Songaila, et al., 1994).

It is not only that this type of measurement is struggling for signal/noise on 4m telescopes, but also for increases in spectral resolution. ***Figure 6*** shows an illustrative model the complex cloud structures seen towards a Quasar absorption system (courtesy of Bob Carswell). The top spectrum is a simulation produced at R ~50,000 with S/N = 50 per 0.01 Angstrom pixel. The lower figure shows the same cloud complex observed with R ~ 120,000 taken at lower signal/noise (~25 per 0.005 Angstrom pixel). The far better contrast of the various cloud components in the lower figure is apparent. Carswell has shown that computing element abundances with multi-component model fitting techniques can achieve two to three times greater precision in these higher contrast spectra than in higher signal/noise lower dispersion measurements — "you get most out of spectroscopy when you resolve the lines" (Carswell 1994). The smaller delivered images that we expect on Gemini will allow us to get more

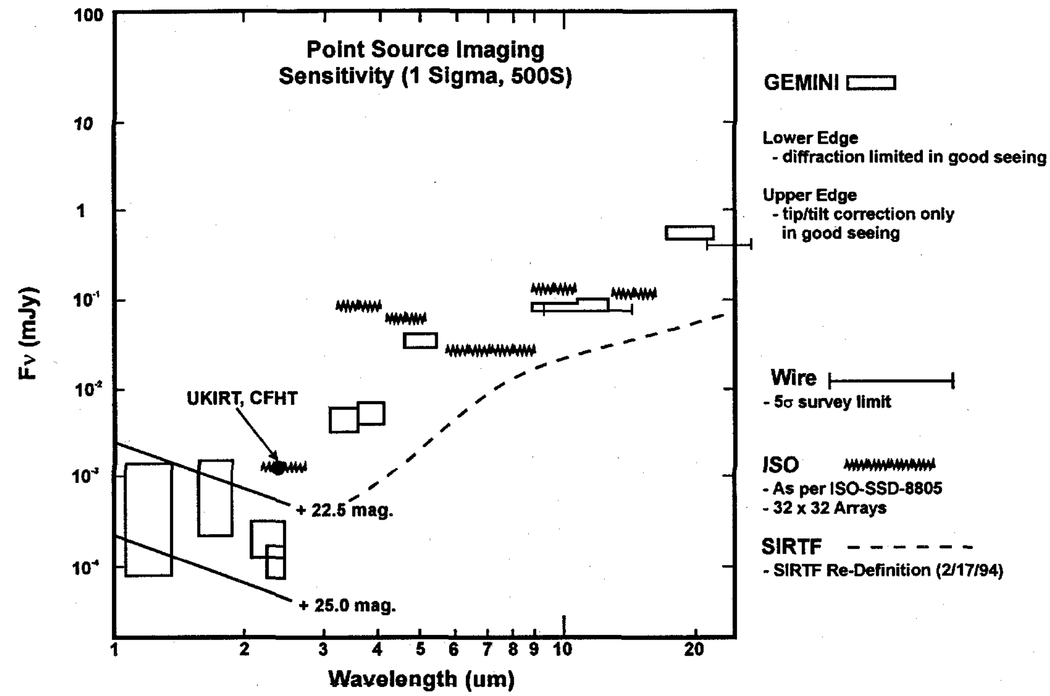


Figure 5. The expected point source sensitivities on Gemini in the infrared. The effect of improving the delivered image quality is shown most clearly in the 1-5 micron region where both tip/tilt and low order adaptive optics will be most effective.

photons through narrower slits — hence we will get the joint benefits of large aperture and higher dispersion. High resolution spectroscopy is likely to undergo a considerable renaissance with the new generation of large telescopes.

It is these types of projects, of which the above illustrations are only a small sample, coupled with a desire to exploit the unique performance gains offered by the Gemini telescopes that has driven the formulation of the instrumentation program.

The Gemini Instrumentation Program

The original instrumentation plan was based on the implementation plan presented to the Gemini Board at its November 1992 meeting. It consisted of the following instruments/capabilities:

Mauna Kea — Optical acquisition camera, 1-5 micron camera, 1-5 micron spectrograph, and optical multi-object spectrograph (MOS).

Cerro Pachon — Optical acquisition camera, high resolution optical/UV spectrograph (HROS), and borrowed IR instruments from CTIO.

Over most of 1993 seven instrument working groups (IWGs) met and actively discussed the individual descriptions and capabilities of the instruments and facilities needed to do science with the Gemini telescopes. Their conclusions are documented in the following IWG reports:

1. Optical Imaging and CCDs — Chaired by Gerard Luppino (Univ. of Hawaii)

2. Multi-Object Spectroscopy — Chaired by Pat Osmer (Ohio State Univ.)

3. High Resolution Spectroscopy — Chaired by Caty Pilachowski (NOAO)

4. IR Imaging and Arrays — Chaired by Jay Frogel, then Chas Biechman (IPAC)

5. IR Spectroscopy — Chaired by Pat Roche (Univ. of Oxford)

6. Adaptive Optics — Chaired by Rene Racine (Univ. of Montreal)

7. Acquisition, Guiding and Wavefront Sensing — Chaired by Charles Jenkins (RGO)

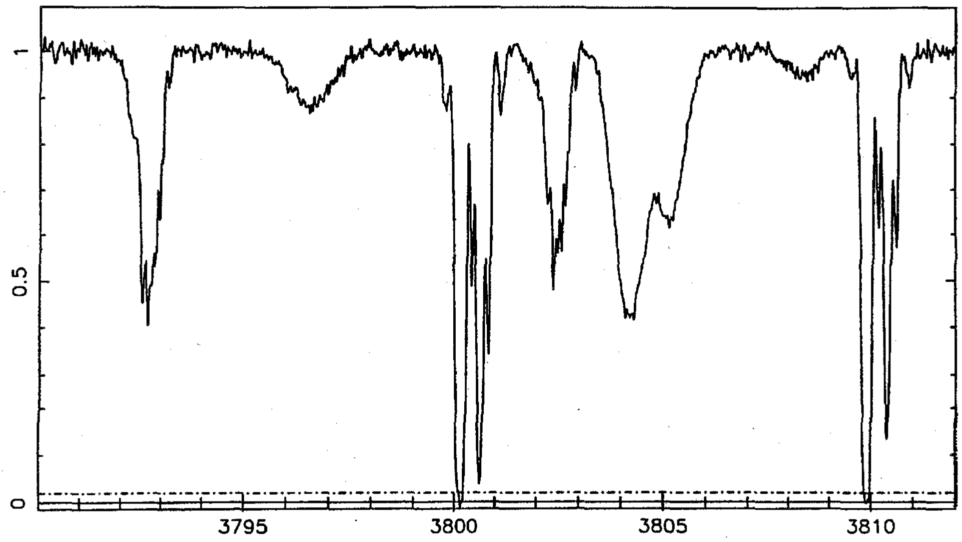


Figure 6(a).
Simulation of a quasar absorption system observed at R ~ 50,000 with S/N = 50

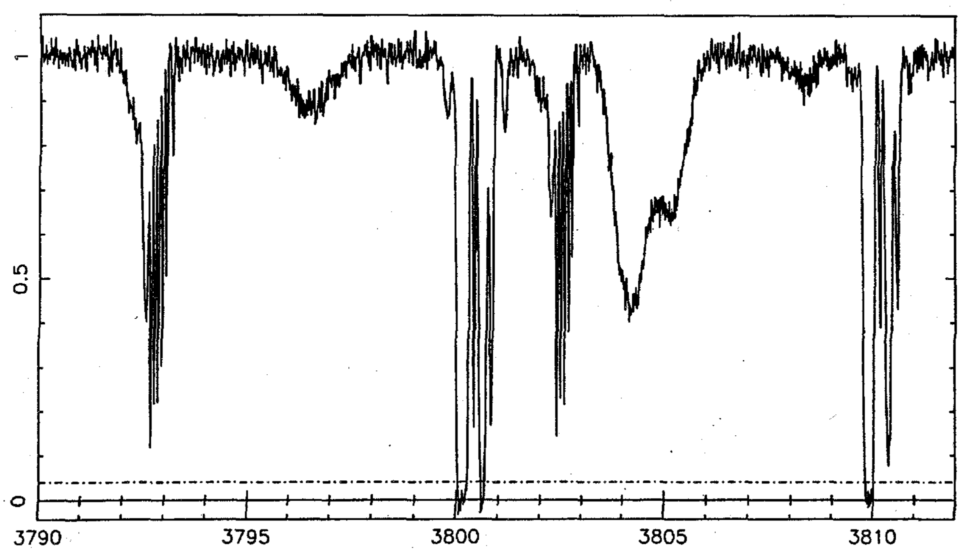


Figure 6(b).
Same absorption system observed at R ~ 120,000 with S/N = 25

The GSC reviewed the reports of these groups at its October 1993 meeting in Tucson and produced a preliminary set of recommendations.

The tasks of wrestling with these recommendations to construct a coherent program that could be accommodated within the schedule and budget of the capital phase of Gemini was undertaken by the Project Scientist team and Gemini Instrumentation Group, principally at meetings at the January 1994 AAS in Washington, in Tucson in early March, and again at the SPIE meeting in Kona in mid-March this year.

The preliminary program was presented to the National Science Advisory Committees in late March and early April, and final feedback from these meetings was brought by the Project Scientist team to the GSC at the 11-13 April meeting this year.

Since the original program was developed, the Project has become the premiere national facility for six participating countries. The 1994 Gemini instrumentation program has to provide world class scientific capabilities to an expanded *and evolving* partnership.

For example in the Canadian case, the recent success of the Hubble refurbishment and continued success of sub-arcsecond imaging and spectroscopy at the CFHT has *heightened interest in exploiting the best tenth percentile* seeing conditions at both Mauna Kea and Cerro Pachon.

Argentina, Brazil and Chile are keenly interested in multi-object spectroscopy on Gemini South. The success of the HiRes instrument on Keck has heightened interest in a high resolution spectrograph, especially in the UK, which will complement Keck — but in the southern hemisphere. Within the US there is a continuing desire to have mid-IR instruments on Gemini, since they would provide a unique and unchallengeable niche for Gemini science. This aspiration has been further heightened by the imminent availability, from US-DoD programs, of large format, new technology mid-infrared arrays.

Consequently, an alternative program was proposed. This program aims to bring more balance to the instrument complement across the Gemini telescopes and to respond more adequately to the aspirations of the evolving and expanded partnership in the following ways:

- Provide a 1-5 micron imager (for science and commissioning) and 1-5 micron spectrograph to Mauna Kea as originally planned.

- Provide a multi-fiber feed from the Gemini f/16 Cassegrain focus to the CFHT coudé spectrograph.

Duplicate the optical MOS instrument (with an integral field and imaging mode), the first MOS being commissioned on Gemini North then moved to Gemini South for first light. The second MOS, which will be constrained to cost no more than 70% of the first MOS, will then be delivered to Mauna Kea.

- Use some of the savings inherent in the above approach to fund a simple but capable broadband 10-20 micron imaging capability that fully exploits the new "deep well" 256 x 256 blocked-impurity-band mid-IR arrays becoming available. This camera should be commissioned on Mauna Kea and be available for use at first light on Cerro Pachon.

- Provide a fully capable Cassegrain OUV HROS for Gemini South with R ~80,000 and/or R ~ 120,000.

- Provide funds to allow the integration and use of CTIO IR instruments on Gemini.

The Gemini Board asked for recommendations for a continuing instrumentation program into the operational phase of Gemini. As will be seen, the instrument planning for operations is a crucial aspect of the overall Gemini instrumentation program.

At its May 1994 meeting in Santiago, Chile, the Gemini Board approved the following resolution.

The Gemini Board, recognizing the long lead time required to deliver state-of-the-art facility class instruments, asked the Gemini Science Committee to prepare an integrated instrumentation program covering the construction and early operation phases of the Gemini Project. The Board has received and approves the program proposed by the GSC which involves the following instruments:

Mauna Kea	Cerro Pachon
Optical Acquisition Camera	Optical Acquisition Camera
1-5 μm Imager	Multi-Object Spectrograph
1-5 μm Spectrograph	High Resolution Optical Spectrograph
Multi-Object Spectrograph	Shared Instrumentation with CTIO
8-30 μm Imager ◄ - -	- - - ► (May be shared between Gemini North and South)
CFHT Fiber Feed	

The Gemini Board approves the allocation of the Instrument Workpackages contained in the Instrument Program as follows :

Chile	United States	Canada	United Kingdom
CCD Electronics (X6)	IR Imager (1-5 mm) IR Spectrograph (1-5 mm) 8-30 mm Imager CCD Development CCD Imager Heads (X2) IR Arrays & Controllers (X2) Acquisition Cameras (X2) WFS CCDs & Electronics (X6)	MOS (X2) [Collaboration] CFHT Fiber Feed	MOS (X2) [Collaboration] HROS

The Board encourages the broad participation of the international communities in the procurement of CCDs and IR arrays through collaborative foundry runs as this may allow for greater capability of the detectors ultimately delivered to the Gemini telescopes.

In addition to this first complement of instruments, we will be developing a continuing instrumentation program to ensure a smooth and effective transition into operations. *This will include discussions with National Observatories* on possible mechanisms for sharing instruments between Gemini and other telescopes, for example, sharing the 8-20 micron MICHELLE Spectrometer with UKIRT and the NOAO Phoenix and SQUID infrared instruments with CTIO.

However, our first priority in the coming months will be the instruments shown on the provisional schedule in ***Figure 7*** — as can be seen, the work required to build these instruments must be started now.

— ***Matt Mountain***
Project Scientist

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1. Carswell, et al., *"Is there deuterium in the z = 3.32 complex in the spectrum of 0014 + 813?"*, 1994 (in press).

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3. Davidge, et al., *"The scientific case for sub-arcsecond spectroscopy on the Gemini 8m telescopes"*, 1994 Gemini Report (in preparation).

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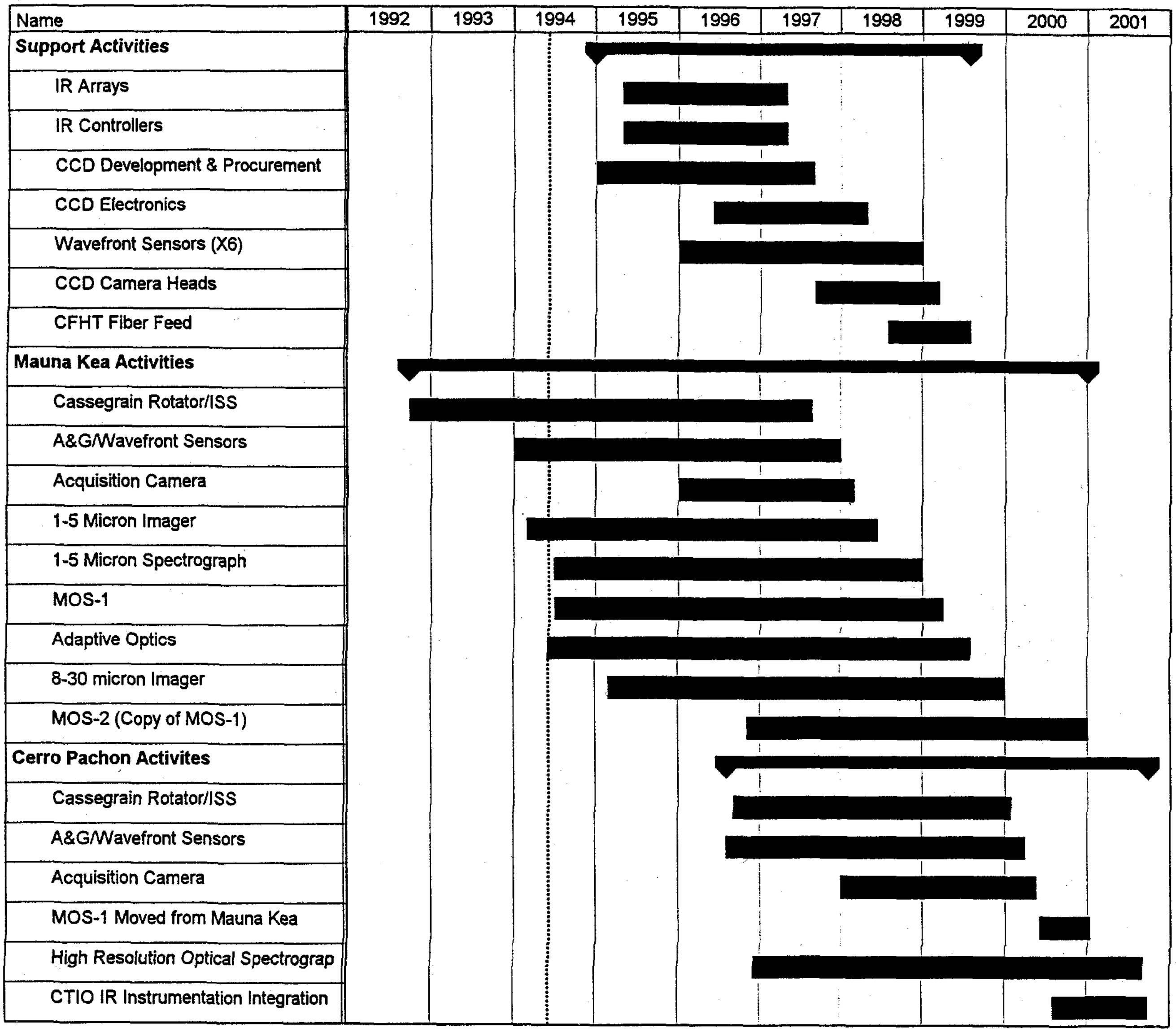


Figure 7. Gemini Instrumentation Program Provisional Schedule

GEMINI GROUP UPDATES

Telescope Structure, Building/Enclosure

Telescope Structure

A major milestone was achieved when the telescope CDR was held on 1-2 March 1994. Prior to the CDR the telescope was reviewed by the Gemini Science Committee and a Safety Committee. The findings of these two independent reviews were presented at the CDR.

The CDR was successful, and the committee recommended moving forward and placing fabrication contracts.

An interface control document for the telescope structure has been completed. All interfaces to the telescope mount structure have been identified and detailed prior to placing fabrication contracts.

The design and fabrication specifications for the telescope have been completed and sent to contractors in many countries for bidding. Bids are due to be returned at the end of May.

Dames and Moore were awarded a contract to develop seismic design criteria for the Mauna Kea and Cerro Pachon sites. They have completed the program and have produced seismic design spectra and ground motion time histories for the sites. This work was completed prior to the CDR and used in the seismic design and evaluation of the telescope structure.

The telescope design is shown in ***Figure 8.*** The figure shows the improved access to the center section access ports, which will allow personnel into the mirror cell for maintaining the primary mirror support system.

Enclosure

After many months of negotiations a contract has been signed by Canadian Commercial Corporation (CCC) for the design, fabrication and site erection of the two enclosures. CCC is a Canadian government organization established to assist Canadian firms to compete for US contracts by entering into contracts directly with the US government (or other organization) and then writing a subcontract with the selected Canadian firm, in our case Coast Steel fabricators in Vancouver. The greater than expected time required to finalize details of this contract have delayed the completion of the Mauna Kea site construction documents by M3 Engineering. Coast Steel Fabricators have now started designing the interfaces between the rotating enclosure and the stationary enclosure base, which must be defined before M3 can complete their construction documents.

Mauna Kea

A 50% design review for the Mauna Kea support facility was held on 14 February and the 95% design review on 27 April. When the construction documents are completed, the Project will send the bid documents to potential contractors.

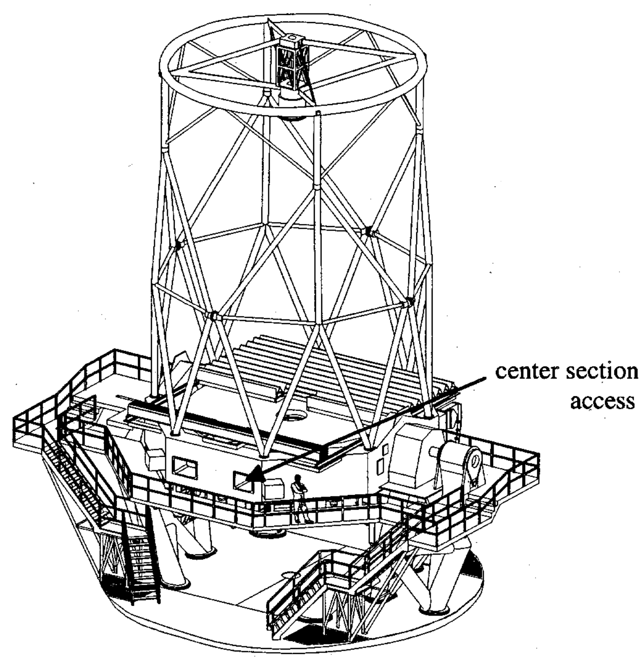


Figure 8. Gemini telescope design

GEMINI GROUP UPDATES

During the design process, M3 Engineering placed a subcontract with Leo Daley, a consultancy firm in Hawaii, to ensure that the design meets applicable local building codes. M3 Engineering also placed a subcontract with Engineering Solutions to advise on the design of the grounding system (including lightning protection), a particularly difficult problem with the low conductivity soils on Mauna Kea and the necessity to avoid ground loops.

A major milestone has been achieved with the approval of the Conservation District Use Permit by the Board of Land and Natural Resources. When M3 engineering have completed the Mauna Kea construction documents, they will be submitted to BLNR for final approval, and also to the County of Hawaii to obtain building permits.

Cerro Pachon

A significant level of activity has started in Chile, with significant contributions from Enrique Figueroa and Hernan Bustos at CTIO, in addition to interaction with other CTIO staff.

Preliminary layouts of the support facility for Cerro Pachon have been completed. Within a few weeks (after completing the Mauna Kea construction documents), M3 Engineering will start the construction documents for Cerro Pachon, working closely with a Chilean architect.

LEN, a Chilean firm, has completed the design of the road that will allow 10m diameter loads to be delivered to Cerro Pachon. Construction will start soon.

TECNAC, a Chilean power engineering firm, has completed the design of the commercial power line from the Cerro Tololo tap-in to the summit of Cerro Pachon. The construction has been bid and a construction contract will be awarded soon.

Karzulovic, has completed a preliminary design for the water supply system. Wells will be drilled at the base of Cerro Pachon, and the water pumped up the east side of the mountain. Construction of a maintenance road leading from the summit of Cerro Pachon to the water well location is nearly completed.

EDIC, a Chilean design firm, has completed documents for the excavation of the mountain to the final level of 2715m. The excavation has been bid and a contract awarded to IMOPAC, a local mining company. The excavation will take approximately two months and started in May. An inspection services contract has been awarded to a geotechnical firm, Serin, to monitor and control the excavation program.

Coating Plant

Royal Observatories have designed the magnetron system for the magnetron sputtering test program that will be performed in the WHT 4.2m coating chamber in La Palma. The tests will be performed between May and July this year.

Protected Silver Coating for the Primary Mirror

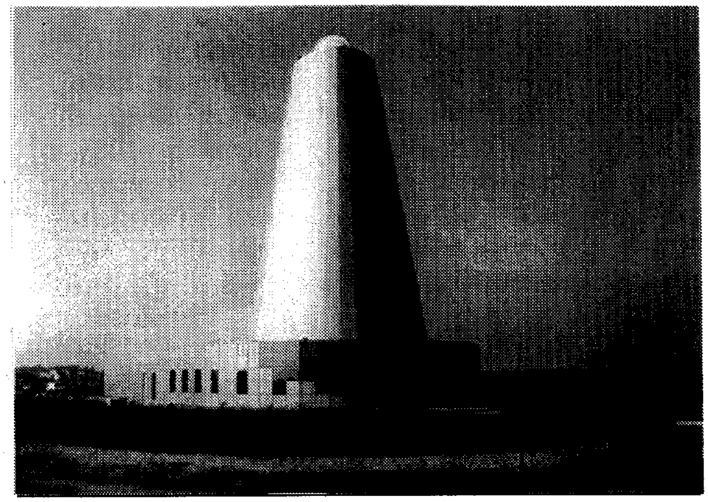
ODA has submitted their second (of 6) quarterly reports on the development and testing of protected silver coatings for the primary mirror. ODA main subcontractors, DSI and AIRCO, have completed the first runs with the hafnia and silicon nitride overcoated samples. Many parameters, including the thickness of the adhesor, silver and protective overcoat layers, were varied to optimize the performance of the coating. The coatings have been characterized using several independent methods. Samples are sent to Helios for 10.6 micron measurements with a laser reflectometer; UV, optical and near IR reflectivities are being measured using a Cary 5E spectrophotometer; IR measurements were made at the subcontractors and at ODA with a Perkin Elmer 983 spectrophotometer; 4 micron measurements are made at NOAO/Gemini using the "Blue Toad". To provide a method for calibrating the samples, gold has been deposited on diamond turned copper beryllium substates, and after characterization, a specimen has been sent to all of the collaborators as reference samples. The reference samples have been calibrated by NPL.

Environmental durability, abrasion resistance and adhesion tests are being performed. The second round of optimization will start in the third quarter.

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

GEMINI GROUP UPDATES

Optics

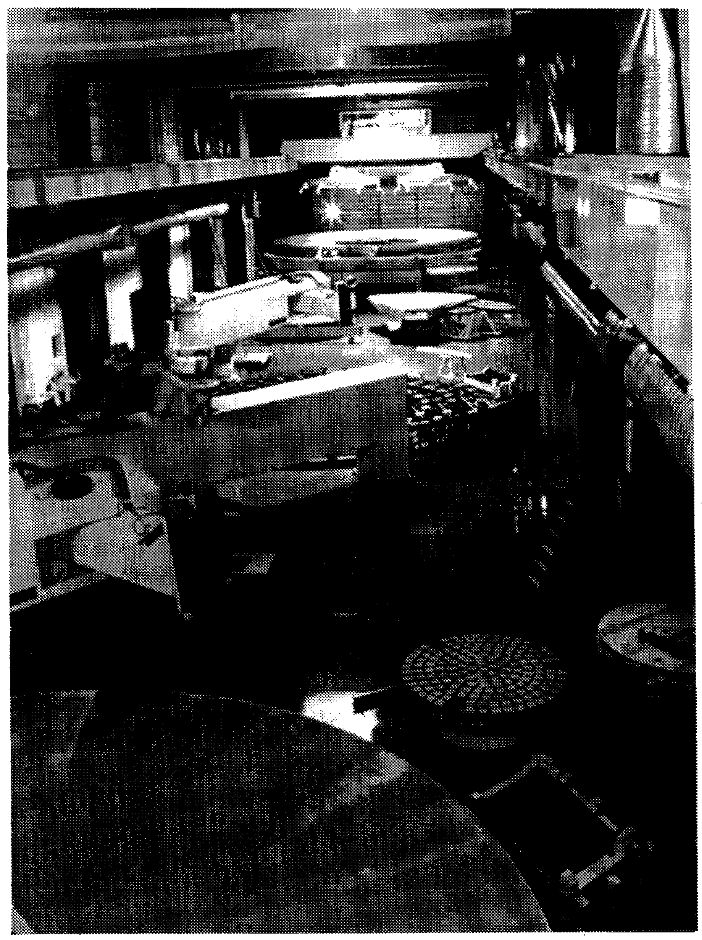


The REOSC 8m Optical Shop in St. Pierre du Perray, France.

Primary mirror polishing contract awarded to REOSC Optique

The French optical firm, REOSC Optique, has been chosen to polish the two primary mirrors for Gemini. The contract also calls for REOSC to transport the mirror blanks from Corning's Canton, NY plant to their polishing facility in St. Pierre du Perray, south of Paris. This transportation will be almost entirely by water, since Corning's facility is only 30 km from the St. Lawrence Seaway, and REOSC's polishing facility is less than 5 km from the Seine River. Transportation of the finished mirrors to the telescope sites is also included in the contract in the form of options that can be exercised by Gemini.

REOSC was previously chosen by ESO to polish the four 8.2-meter primary mirrors for the VLT. The REOSC 8-meter polishing facility is already complete, as shown in the photographs (*opposite*). Fine grinding of the first VLT mirror has just been completed. At least three of the VLT mirrors will be finished before the Gemini mirrors, providing REOSC with extensive experience that is directly applicable to the Gemini work. The shipping container used to transport the Gemini blanks will be patterned after the container already used by REOSC to successfully transport the first VLT blank.



An internal view of the REOSC facility showing the first VLT mirror blank in the background.

Progress at Corning on the mirror blanks

Corning is making good progress on the Gemini primary mirror blanks. Glass production for the first mirror is complete, and as of May 10, 35% of the glass had been produced for the second mirror. All of the boules of ULE™ for the first blank have been inspected, measured, fused together into two-boule stacks and machined into hexagonal blocks, ready for fusing into the complete mirror. The Corning contract was recently amended to include blank generation. With the addition of this process step,

GEMINI GROUP UPDATES

delivery of the first Gemini blank will now be in October, 1995.

The Gemini mirrors are following the 8.3-meter mirror blank being manufactured for Subaru, the Japanese National Large Telescope. During our visit to Corning in early April we had a chance to see the Subaru blank in its flat state, before slumping to the final curved shape. It is an extremely good looking blank, with very few bubbles or inclusions and excellent quality fusion seams. We are confident the Gemini blanks will be of comparable high quality.

A joint meeting involving Gemini, Corning, and REOSC was held April 8, to discuss handling and transportation of the blanks. Both Corning and REOSC have been cooperative and flexible, and it is a pleasure to work with both companies.

Primary Mirror Assembly Work Package

Optics Group staff have been working with our partners at the Royal Greenwich Observatory and Rutherford Appleton Laboratory to conclude a work package agreement for the detailed design and fabrication of the Primary Mirror Cell Assembly. Because of the complexity of the assembly and its extensive interfaces with other parts of the telescope, we have developed a detailed Work Scope document that defines the design requirements, management plan, work breakdown structure and schedule. The agreement is now in the final stages of negotiation.

Other Optics Group Activities

A conceptual design review for the f/16 secondary mirror assembly was held March 3. The meeting provided a review of the design requirements and conceptual design prior to the release of a Request for Proposal for the design and fabrication of the tip-tilt systems. A Preliminary Design Review of the structural design for the F/16 secondary mirror was held May 9.

Optics Group personnel and our partners in the UK presented several papers on Gemini at the SPIE Symposium on Astronomical Telescopes & Instrumentation for the 21st Century at Kailua Kona, Hawaii, where I had the privilege of serving as Chair of the Advanced Technology Optical Telescopes V conference. These papers include:

Gemini Primary Mirror Support System, *L. M. Stepp, E. W. Huang, M. K. Cho*

The Manufacturing Feasibility, Assembly and Testing of the Gemini Mirror Cell, *J. Lidbury*

Design and modeling of a 1-m Silicon Carbide f/16 Secondary Mirror for the Gemini 8-m Telescopes, *E. R. Hansen, J. L. Roberts*

Optimization Strategy of Axial and Lateral Supports for Large Primary Mirrors, *M. K. Cho*

The Gemini Primary Mirror Thermal Management System, *R. J. S. Greenhalgh, L. M. Stepp, E. Hansen*

These papers are included in a compendium of Gemini SPIE papers, Gemini document number RPT-PS-G0029, which is available on request.

— ***Larry Stepp***
Optics Manager

GEMINI GROUP UPDATES

Controls

The Controls Group has been focused on three main activities since the last newsletter: preparing for the preliminary design review of the software design description, starting several key work packages, and continuing the servo simulation of the telescope.
The Tucson Project Office is fortunate as well to have Steven Beard from the Royal Observatories visiting for a six month secondment to work with the design team. This has proven to be a very effective way to involve the partner countries in the project, and we would encourage other interested parties to follow the United Kingdom's lead.

Software Preliminary Design Review

The preliminary design review focused on the document *Software Design Description (SDD)*. The review committee was made up of members from the partner countries as well as external members from other large software projects. The PDR committee members are:

- Bob Dalesio - LANL
- Robert Laing - RGO
- William Lupton - KECK
- Bob Marshall - NOAO
- Chris Mayer - RGO
- Rick Murowinski - DAO (chair)
- Gianni Raffi - ESO/VLT
- Malcolm Stewart - ROE
- Pat Wallace - RAL
- Richard Wolff - NOAO

The committee has created a draft report, which will be fleshed out and finished by the end of May, 1994. A brief synopsis of their report is:

The committee finds that the SDD represents a large and generally well executed piece of design work. The complex interactions in a system of this size are explained in an understandable manner. This design and the processes which led up to it reflect the commitment of the controls group to build a system which meets the users' needs - even when those needs are currently poorly defined - if at all.

The charge to the PDR committee was as follows:

The PDR Committee is asked to serve in an advisory role to the project and to submit a report to the Gemini Controls Manager. This report will review the Software Design Description contained herein.

We would appreciate the review committee making a recommendation based on a majority opinion. This recommendation should be one of the following:

- *recommended without conditions or reservations*
- *recommended with conditions - conditions listed; conditions would be action items that need to be satisfactorily discharged*
- *recommended with reservations - reservations listed; reservations would be potential problems that require substantial additional work*
- *not recommended - reasons listed*

The current "count" is 3 reservations, no conditions, numerous comments, and no areas *not recommended*. This represents a job well done by the Software Design Team of Steve Wampler (Gemini), Kim Gillies (NOAO), and Steven Beard (ROE). Substantial portions of the current design were contributed by Pat Wallace, Robert Laing, Chris Mayer, Andrew Johnson and Peregrine McGehee.

Gemini found the process extremely worthwhile and would like to thank all the reviewers for their time and effort. Gemini would like to especially thank KECK, LANL and ESO/VLT for making staff available.

GEMINI GROUP UPDATES

The Controls Group is currently assessing all of the input from the review and will be issuing a response in the near future.

— ***Rick McGonegal***
Controls Manager

System Software

Software Design Description

The group has developed a single document describing the fundamental behavior of the Gemini Control System, merging and fleshing out information previously found in numerous other documents. The intent has been to provide a central document providing an outline of the control system functionality suitable as a starting point for detailed design work by the various Work Package Groups.

Special emphasis has been placed on the functionality provided by the Observatory Control System - that part of the system that is responsible for the user interfaces into he system, overall scheduling, and sequencing of the other system components. The goal of the OCS design has been to provide an environment that makes it easy for observers to use the Gemini Telescopes conveniently and efficiently.

Another area of emphasis is on the major system interfaces between the major systems that comprise the Gemini Control System, as well as external interfaces between the GCS and its users.

The presentation of the design uses prototype console screens to introduce system functionality and makes heavy use of reference scenarios to describe and test system behavior. This approach complements the formal design presentation that is also part of the document.

The Software and Controls group held a preliminary design review on this Software Design Document during April 28-29 of this year and is currently preparing it for a critical design review in August.

The SDD is available via the Gemini gopher server:

gemini.tuc.noao.edu

and through anonymous FTP:

gemini.tuc.noao.edu:~ftp/gemini/SDD

which is a directory containing several different packages for the document. See the Read.Me in the same directory for details. Be forewarned that this is not a small document; it is best printed out on a duplex (double-sided) printer of reasonably high-speed, or else printed during off-hours!

Reference Scenarios

The use of reference scenarios describing the Gemini Control Systems behavior using 'typical' operating sequences has proven to be a useful tool in helping develop an understanding of system operation. These operating scenarios pose problems that the control system must manage effectively in a general manner. That is, each specific scenario represents a class of operating sequences that the telescope control system must properly support.

The group has, in cooperation with scientists and telescope designers from the partner countries, identified these reference scenarios. The group is currently involved in fleshing out the detailed requirements of each scenario before testing the system design against each. The scenarios cover all aspects of telescope operation, from complex observing tasks through engineering and commissioning activities to system responses to failures.

These scenarios and the system's behavior with each are to become part of the Software Design Document as well as the Operation Concept Definition.

— ***S. Wampler***

Real Time Software

Controls Meetings at RGO 11-15 April 1994

During the week of 11-15 April a number of meetings were held at RGO in Cambridge to discuss two of the Gemini control system work packages. On April 11th and 12th the System Design Review for the Standard Instrument Controller (SIC) was successfully conducted. The remainder of the week was spent defining the Primary Mirror Control System (PCS) work package.

GEMINI GROUP UPDATES

Standard Instrument Controller System Design Review

The SIC work package mission is to provide for all other Gemini real-time work package developers a standard EPICS-based control system. Although the EPICS system supports a wide variety of VMEbus hardware, there are several interfaces that Gemini requires (DC Servo Controllers, Bancomm GPS/Time Systems,VMIC Reflective Memory) that are not currently part of the official EPICS distribution which will be implemented by this work package. The SIC work package is now well under way towards a Preliminary Design Review, which will be held later on this summer.

The principal attendees were the Gemini Work Package Responsible (GWPR - P. McGehee), the RGO Work Package Responsible (WPR - A.Johnson), the UK management representative (M. Stewart), and the Gemini management representative (R.McGonegal).

Primary Mirror Control System Discussions

Another Gemini work package to start soon at RGO is the Primary Mirror Support Control System, which is responsible for providing software and controls for the Active Optics System, Defining System, Air Pressure Support System, Safety System, and a Calibration and Test System. Of chief concern will be the control of the Mirror Support Units under development at RGO, which implement both the Active Optics and Passive Defining Systems. The SDR for the PCS work package is currently slated for August of 1994.

The first day and a half of the meeting discussed the technical aspects of the work package and involved the Gemini Optics group, the Gemini Controls group, the Gemini Systems Engineer (J.Oschmann) and the RGO Controls and Mirror Support representatives.

Following on from these initial discussions, a more detailed discussion took place between the GWPR (P. McGehee), WPR (J.Maclean), and the UK management representative (M. Stewart). The results were an outline costing of both hardware and software which show that the budget and schedule proposed for this project by Gemini are realistic.

EPICS Consortium

The Experimental Physics and Industrial Control System (EPICS) toolkit is the foundation of the Gemini real-time control system work packages. Originally developed by the U.S. High Energy Physics community for beamline control and data acquisition, EPICS is now proposed for use by a number of astronomical sites.

On March 7-10 of this year, the latest of a series of EPICS Consortium collaboration meetings were held at the Los Alamos National Laboratory in New Mexico. Representatives from three astronomical projects (Gemini, William M. Keck Observatories, and the Caltech LIGO project) were in attendance. The next collaboration meeting is scheduled for June 13-16 at the Advanced Photon Source, Argonne National Laboratory, Chicago.

The primary information source on EPICS is the Mosaic home page for the Advanced Photon Source Control Group which can be found at:

http://epics.aps.anl.gov/asd/controls/controls.html

This includes hardware and software documentation as well as information on the EPICS consortium's list-server groups.

— P. McGehee

Servo Control

Tracking Simulation

Improvements continued to be made on the tracking simulation in preparation for handing it off to John Wilkes of RGO. A number of relatively minor error sources were added, including drive wheel eccentricity, motor torque cogging, torque constant variation, and tachometer errors. Realistic current and voltage limits were applied in order to make the simulation accurate for larger step commands. The simulation has been kept busy running on weekends and evenings to produce long parameter variation runs to show the effect on image smear of different values of relative friction, stiction/coulomb ratio, and tracking rates.

Selection of Telescope Drive Motors. Motors have been selected for the altitude and azimuth drives. Working

GEMINI GROUP UPDATES

closely with Inland Motor, specifications were developed for making sure that the motors met the required peak torque, steady state torque, cogging error torque, motor torque variation, and thermal characteristics.

Electronic Design Specification. The Electronic Design Spec was finished with ASA after several rounds of revisions and added comments.

Telescope Critical Design Review. The telescope CDR was supported in early March by preparing a paper and presentation describing the tracking simulation and tip-tilt secondary control. Much of the same paper was used later in March for the SPIE conference in Kona.

Telescope Windshake. Analysis of telescope windshake has continued. The image smear error due to shaking of the enclosure has been included. The controller had to be slightly redesigned to include a lead-lag in order to provide a bit more phase and improve damping. This new controller improves performance slightly at lower frequencies (such as windshake) at the expense of amplifying ome of the high frequencies (such as image centroiding errors). The net effect on image smear error seems to be beneficial.

Chopping Reaction Torques. Chopping of the secondary mirror has been examined to determine the motion of the telescope due to reaction forces. The current results seem to indicate that the problem is noticeable but not debilitating.

— M. Burns

Visiting with the Tucson Project Office

I joined the Gemini controls group on March 1st 1994 for a six-month posting from the Royal Observatory Edinburgh (ROE). My objective is to help write the Software Design Description for the high level Gemini Control System and see it through its Preliminary Design Review and Critical Design Review stages. I return to ROE in September 1994. Here at the Gemini office I am working with different tools from the ones I used at ROE. I find the FrameMaker word processor very intuitive to learn and easy to use (apart from the graphical tools, which I find a little fiddly). The TSEE Computer Aided Software Engineering (CASE) tool is very similar to the "Software Through Pictures" tool I use in Edinburgh. Both tools are quite easy to use but have their own rather different idiosyncrasies.

— S. Beard

GEMINI GROUP UPDATES

Instrumentation

The Group has been busy on a number of fronts lately both with the instruments and other facilities within the program. Here is a short précis on each of these activities.

Instrumentation Plan

The Phase 1 Instrumentation Plan has now been formulated and was approved by the Gemini Board in late May. We believe that we now have a well-balanced program both from the perspective of overall functional coverage and split between the northern and southern telescopes.

1-5μm Imager

A scope of work and a schedule have been agreed between the Project and the University of Hawaii for the 1-5μm Imager Conceptual Design Study. A contract has been prepared and is at present with the U of H to be signed. The main milestones for the first phase of this instrument are: Tradeoff study review in early September and the actual CoDR in mid to late November.

1-5μm Spectrometer

This instrument has been awarded as a Gemini workpackage to the US community. In line with US procurement procedures the workpackage will be competitively bid. In order to assist the project's already stretched manpower resources, the initial stages of this procurement will be managed by the US Gemini Project Office (USGPO). An Announcement of Opportunity will be released by the USPGO in the very near future and an RFP will be prepared jointly by the USPGO and the Gemini Project Office. The USPGO has drawn up a set of procurement guidelines, which have been approved by the NSF. Assuming that the procurement procedure advances with no delays, we are confident that a contract for this instrument will be placed early next year.

Cassegrain Cluster

The central components of the Cassegrain cluster, as we now call it, (rotator, instrument support structure, cable wrap) will have its PDR on the 15th and 16th June in Tucson. The PDR committee will be Dan Blanco (Chair) from the WIYN Project, Martin Fisher, Royal Greenwich Observatory, Peter Gray, Steward Observatory and Donald Pettie, Royal Observatory Edinburgh. There will also be other representatives from the National Project Offices and from the project staff. The main items that will be reviewed are:

- Preliminary mechanical design of the rotator, ISS and cable wrap
- Preliminary modeling of the rotator control system
- Interfaces to the A&G system, instruments, adaptive optics and telescope
- Thermal management system
- Instrument handling

We will provide a report on the PDR in the next newsletter.

A&G

The A&G (plus active WFS, Calibration etc.) is a UK workpackage. There now exists an agreed workscope for this activity, which will take us up to the PDR, which is scheduled for mid-November. The Workpackage Manager for this activity is David Gellatly (RGO) and the Workpackage Scientist is Charles Jenkins (also RGO). They are at present assembling a team in order to meet the PDR deadline. Although this Workscope has only recently been signed, there has been a lot of prior discussion as well as a number of productive meetings specific to this activity.

The A&G system is housed within the instrument support structure, and therefore the interfaces in this area are critical. Although the UK is responsible for managing the A&G activity, the overall integration of the Cassegrain Cluster, of which the A&G is part, will remain under the management of the Gemini Instrumentation Manager in Tucson.

GEMINI GROUP UPDATES

Adaptive Optics

We are presently negotiating a Workscope for the adaptive optics system (a Canadian Workpackage) with the Canadian Gemini Project Office (CGPO). This Phase 1 Workscope will cover the work up to the Conceptual Design Review scheduled to take place in January 1995.

Although we have not yet agreed upon a scope of work, there has been some activity by the CGPO in looking at potential optical designs for the AO system. This work has been carried out by Harvey Richardson at the University of Victoria and is progressing well.

Work with Starfire

We finally have a signed CRDA with the Starfire Optical Range, Air Force Phillips Lab, for collaboration in the analysis of potential adaptive and active optics systems for Gemini. Our association with the SOR, and in particular with Dr. Brent Ellerbroek, has been tremendously helpful and we are glad to see it continue on a more formal footing.

Some of the work that Brent has done for us in the past has included: Analysis of natural guide star and laser guide star low-order adaptive systems as applied to Gemini, performance analysis of Shack-Hartmann wavefront sensors for Gemini and tip/tilt performance analysis. Future efforts will involve working with both the UK and Canada on analysis of the proposed active and adaptive optics systems, providing an analysis of the full closed loop system's models as they would perform on Gemini.

— D. J. Robertson
Instrumentation Manager

Reports from the National Project Offices

From the US Project Office

As many of you are already aware, there are new personnel in the US Project Office and with that, and the upcoming instrument activities, we are preparing for a more active role within the US and with the International Project Office.

In January 1994, Todd Boroson was appointed as the US Project Scientist. Todd was previously a staff member at Carnegie Observatories, University of Michigan/MDM Observatory and most recently at Kitt Peak National Observatory of the National Optical Astronomy Observatories (NOAO). With this appointment Todd joins Malcolm Smith and Jacques Beckers as Associate Directors of NOAO. The US Gemini Project Office (USGPO) is a new division of NOAO.

Fred Gillett continues to provide his technical expertise as Associate Project Scientist and Larry Daggert, head of NOAO's Engineering and Technical Services Group, continues to provide engineering support. Kathy Wood joined in February to provide support in technical administration matters relating to the US-allocated instrument procurements and in the Gemini advocacy role the USGPO has within the US.

The USGPO is actively working to support the instrument definition for Gemini and is preparing for the competitive procurement of the US-allocated instruments. A meeting was held April 5 and 6 of the US Science Advisory Committee, which focused on these issues in preparation for the Project Scientists meeting and the following GSC meeting.

On an international note, we are pleased to support Brazil in a Portuguese translation of the USGPO brochure which was published in January.

Our offices are located in the NOAO building in Tucson, near to but distinct from the International Gemini Project Office. We can be reached by e-mail (usgpo@noao.edu), FAX (602-322-8596), telephone (602-325-9352) or USGPO, PO Box 26732, Tucson, AZ 85726.

— ***Kathy Wood***

Reports from the National Project Offices

Faint object optical spectroscopy with Gemini

— *Simon Lilly*
University of Toronto

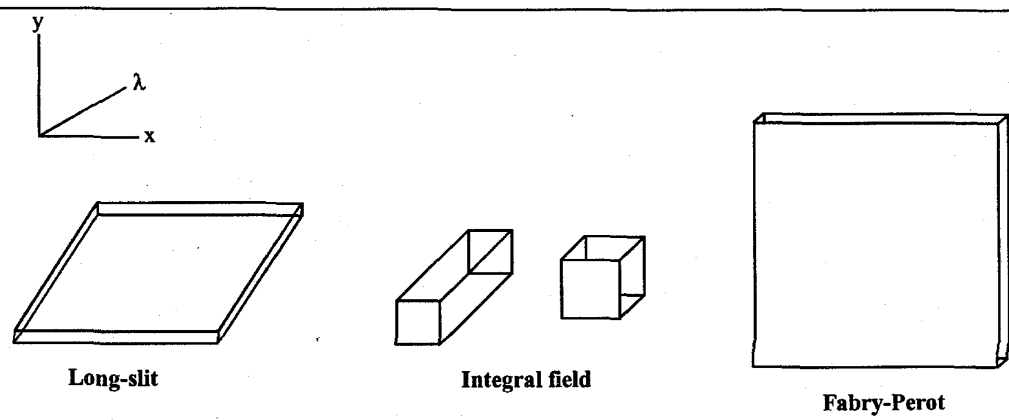
NOTE: The following was extracted from a longer paper by the author. Please contact him directly if you would like the complete paper. (lilly@perceval.astro.utoronto.ca)

Integral field spectroscopy

Integral field spectroscopy is the technique whereby spectral information is gathered from a contiguous two-dimensional region on the sky. It is best viewed in the context of the information stored on a CCD. A CCD has a finite number of pixels which can be used to record information from the sky: this information can be spatial or spectral and can be viewed as sampling a fixed volume of position-wavelength space (*see figure below*). Different types of spectrograph have different geometries of this sampled volume. In a Fabry-Perot spectrograph (or indeed in broad- or narrow-band imaging) the full two-dimensional spatial information is recorded for a single wavelength element. In a long-slit (or multi-object slitlet) spectrograph, one spatial dimension is eliminated and information is recorded from a large extent of the other spatial dimension. In multi-object formats, the wavelength range can be truncated to allow the use of multiple slitlets in the dispersion direction increasing the multiplexing advantage. In the type of integral field spectrograph to be discussed here, the spatial information is gathered from a two-dimensional region. It is again possible to increase the spatial area with the curtailment of some spectral information.

The two-dimensional spatial sampling can be achieved through the use of a fibre bundle of a lenslet array in the focal plane (e.g. TIGER at CFHT). As an example of a specific integral field spectrograph, ***Table 2*** gives the parameters for the TIGER (1500 lenslets) and ARGUS (650 fibres) modes of the OASIS spectrograph being built for CFHT. The spectrograph also has a long-slit mode in which the slit is up to 90 arcsec in length. The throughput of the existing experimental TIGER spectrograph on CFHT is "comparable" (i.e. within 10-20%) of the highly efficient MOS spectrograph.

The main difference between integral field spectrographs and long-slit/multi-slit spectrographs is obvious: the former provide zero- or one-dimensional data on objects over a relatively wide field whereas the latter gives two-dimensional data on an extended object or group of objects over a much smaller field. In general terms the multi-object spectrograph may thus be thought of as a "survey"



Conceptual illustration of integral-field spectroscopy as a sampling of the information volume (two spatial dimensions and one spectral). The four solids have equal volume.

Reports from the National Project Offices

MODE	Spatial Sampling (arcsec)	Field of view (arcsec^2)	Spectral Resolution	Range (A)
TIGER	0.1	3.6 x 2.9	3040	440
			620	1980
	0.15	5.4 x 4.4	2900	440
			600	1980
	0.3	10.8 x 8.7	2490	440
			510	1980
	0.5	18.0 x 14.5	1950	440
			400	1980
ARGUS	0.23	6.0 x 4.5	1260	2250
			280	6000

Table 2. Parameters of the f/20 OASIS spectrograph (CFHT 1996)

instrument whereas an integral field device is more of a "single-target" device.

The level of imaging performance in astronomy has improved greatly in the last five years with the exploitation of superb ground-based sites such as Mauna Kea, the use of simple low-order AO techniques and the launch of HST. This trend will continue, with the successful repair of HST, the construction of optimized telescopes such as Gemini, and the development of higher order AO systems. This veritable revolution in imaging has re-emphasized that many objects of interest in the Universe are complex and extended two-dimensional sources of emission that can not be adequately studied in one-dimension. This in turn has spurred the interest in integral field spectrographs.

As a simple illustration of the power of integral field spectrographs, the images in ***Figure 9*** on the following page show the possible sampling of various familiar objects with an integral field device. These have been chosen to demonstrate the need obtain two-dimensional spectroscopic data on these objects. Some of the images (e.g. that of NGC 4151 and 4C41.17) are taken from HST, and are at a higher resolution that will be obtained with Gemini. Others are at the best Gemini resolution and some are at about 1 arcsec resolution. The image of 3C265 shows a case where the field of view has been extended to almost 20 arcsec by making each entrance aperture 0.4 arcsec in size.

These images illustrate that structure is present in these objects and that a full understanding of the physics in each case could not possibly be acquired with a slit spectrograph that had slits small enough (0.2-0.3 arcsec - typically the entrance aperture of each element of the integral field array) to make full use of the superior image quality that Gemini will produce.

Aside from the obvious differences in the sampling of the information volume, integral field spectrographs of the OASIS type have a number of other beneficial features:

(a) the positioning of the aperture relative to the object is not critical and can be accurately recovered *a posteriori* in the reduction process by summing the flux in line of continuum, etc. through each channel to produce an image.

(b) the spectral resolution, as defined by the entrance (or lenslet size, etc.) can be matched to a spatial scale that is smaller than the image size. This allows relatively high spectral resolution with a grism.

(c) The spatial PSF can be optimally sampled in both spatial dimensions of the PSF without either loss of light (slit losses) or the wavelength uncertainty that arises from uncertain positioning of an object in the aperture. The lenslets/fibres operate here like an image-slicer in a high resolution spectrograph. The only constraint is that the total number of "channels" is constrained by the size of the CCD so the smaller you make the "pixels" in the focal plane the smaller the total field of view.

(d) poorer than expected image quality simply produces poorer than expected spatial resolution in the final data - it does not produce the loss of slit-throughput or loss of spectral resolution as encountered with slit spectrographs.

Reports from the National Project Offices

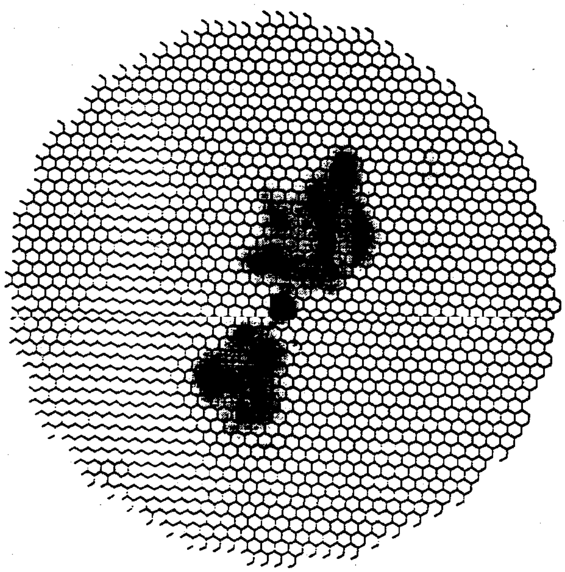


Figure 9(a). 0.1 arcsec apertures = 4 arcsec diameter
The nucleus of NGC 4151 in [0III] 5007 observed with HST (0.1 arcsec resolution), with an overlay at a 1500 aperture lenslet array with 0.1 arcsec apertures. Although the image is at higher resolution than is likely to be achieved without AO on Gemini, they demonstrate that structure is present in the object 0.3 arcsec scales. High resolution images such as these will be available to augment the lower resolution Gemini spectroscopy. The difficulties of understanding this object with narrow arcsec slits are obvious.

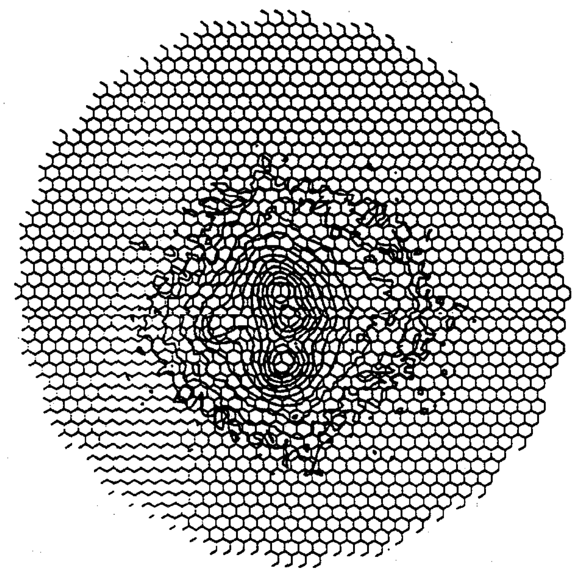


Figure 9(b). 0.2 arcsec apertures = 8 arcsec diameter
The gravitational lens [422+231] observed with CFHT (0.35 arcsec seeing), with a 0.2 arcsec lenslet array. This image is more typical of the expected non-AO performance of Gemini.

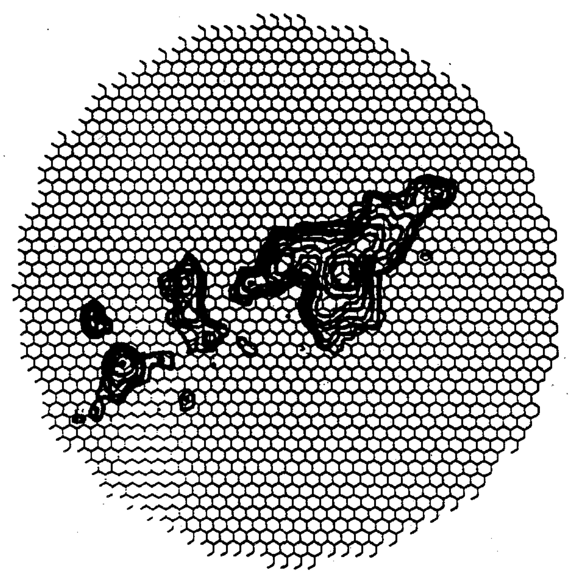


Figure 9(c). 0.4 arcsec apertures = 16 arcsec diameter
The z = 0.8 radio galaxy 3C265 observed with CFHT (1 arcsec resolution), with a 0.4 arcsec lenslet array. An example of the use of rather large apertures to give a wide field of view on a complex two-dimensional object.

The principal perceived technical disadvantage of integral field spectrographs is that they may be less easy to flat field than slit spectrographs on account of the well-defined and constant slit profile in the latter. This may not be a large problem in practice, especially for observations of prominent emission lines and absorption lines: The prototype TIGER spectrograph on CFHT (equivalent to the TIGER mode of OASIS) already achieves sky subtraction per pixel at the 0.5% level equivalent to a surface brightness of V = 26.7 mag/arcsec^2 (assuming a V sky brightness of 21 mag/arcsec^2). However, this may be a concern where precise continuum measurements are required, say in the determination of equivalent widths on very faint objects or in the identification of objects of unknown redshifts. The flat fielding of integral field spectrographs is clearly a demanding problem but one that should be solvable with sophisticated software, since the geometric stability of an integral field spectrograph need not be worse than of a conventional slit spectrograph.

Practical designs for integral field spectrographs (particularly those utilizing lenslet arrays) are also likely to curtail the wavelength range observable in a single exposure. This may have some scientific impact since studies of line ratios, etc. have traditionally been done with the lines observed simultaneously. The need for such simultaneous observations arises in part because of the difficulty, with a slit spectrograph, of repeated accurate location of the entrance aperture on the object and the effects of differential refraction effectively moving the object relative to the entrance slit. Both of these effects are eliminated with an integral field spectrograph because, especially if the spatial PSF is oversampled, the positioning of the entrance apertures relative to the target object can be recovered *a posteriori* as a function of wavelength.

Integral field spectroscopy in the context of Gemini science goals

From the above discussion, it will already be clear that long-slit/multi-slit and integral field spectrographs are complementary in their capabilities and that both are likely to be required for Gemini to meet its scientific goals. The following table summarizes the features of a given observation that are best suited to a long-slit/multi-slit spectrograph and to an integral field device.

Long-slit / multi-slit spectrograph	**Integral field spectrograph**
Multiple targets distributed over large field with average separation > 5 arcsec	*Spatially extended single target in which 2-dimensional information is desired or close group of multiple targets separated by < 5 arcsec*
	Complex target in which *a posteriori* positioning of aperture important
	Maximum wavelength accuracy due to optimal sampling of PSF*
	Minimum slit losses due to optimal sampling of PSF*
Precise continuum data due to superior flat-fielding and sky-subtraction#	

Summary of observation features optimized in long-slit / multi-slit and integral field spectrographs. The items marked * and # are based on the optimal sampling of the PSF and the likely improved flat-fielding respectively.

Reports from the National Project Offices

From the UK Project Office

Recent Shift-and-Add Results from IRCAM on UKIRT

In April an infrared camera system with a 256 x 256 InSb detector from SBRC was installed in the 3.8m UKIRT. The array is read out and processed by a powerful system called ALICE, which is capable of 100% efficient shift-and-add processing over the whole array at 30 Hz.

Results are shown in ***Figure 10***. At 2.2 μm 30% of the energy of a star is concentrated in a core with a FWHM of 0.15 arcseconds. At 3.8 μm the asymetric diffraction pattern reveals imperfections of the telescope optics. Project Scientist, Phil Puxley of the Royal Observatories describes other results from the new camera in the latest UKIRT Newsletter.

— ***Terry Lee***
UK Project Manager

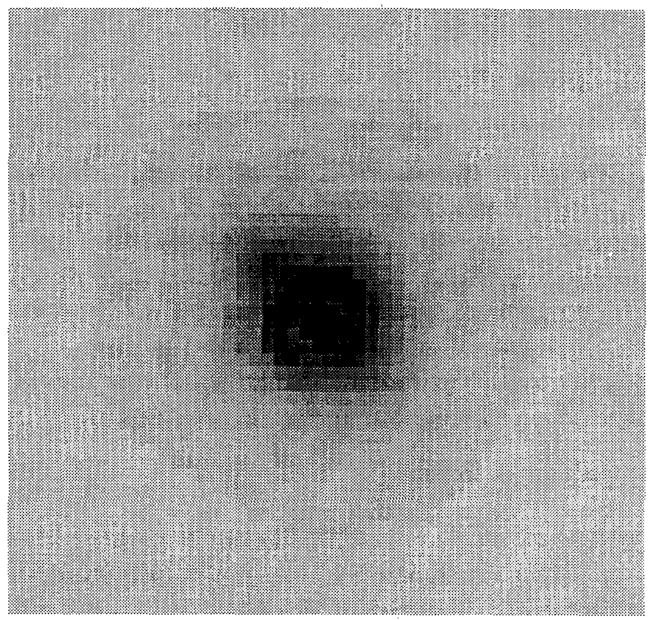


Figure 10(a). A K-band (2.2μm) image of a star made through shift-and-add processing is shown.

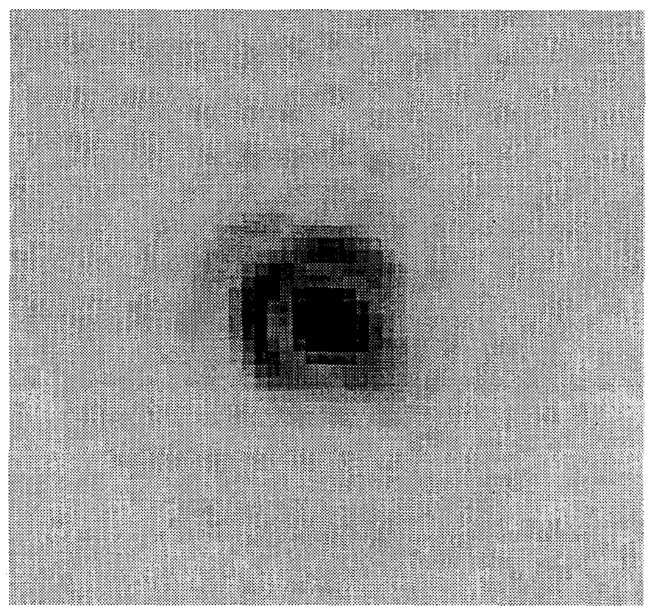


Figure 10(b). Same as Figure 10(a) but narrow band L was used.

GEMINI
8-M Telescopes Project

950 N. Cherry Avenue
P.O. Box 26732
Tucson, Arizona 85726-6732
Fax: (602) 322-8590

The following technical report has been published by the Gemini Project since the last edition of the Gemini Newsletter (January 1994). Copies of this and other publications are available on request by contacting the Gemini Project at the above address, Fax number or by E-mail (lfriedmn@gemini.edu), attention: Linda Friedman, Documentation Coordinator. Specific report numbers are listed following the author(s) name in parenthesis.

Technical Reports

March 13-18, 1994 — Papers submitted to S.P.I.E.'s 1994 Symposium on Astronomical Telescope & Instrumentation for the 21st Century (RPT-PS-G0029)

Effective May 23, 1994, the Internet address for all Gemini Project personnel became:

name@gemini.edu.

E-mail addressed as (name@noao.edu) will still reach the project.