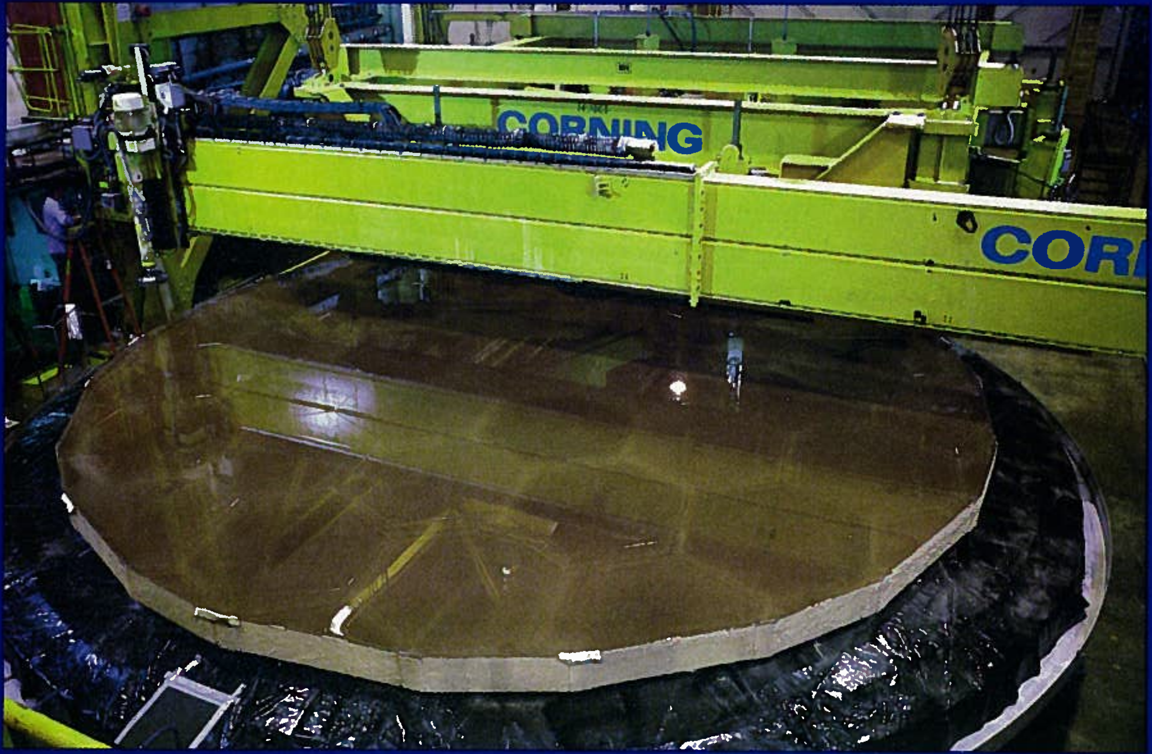
GEMINI

NEWSLETTER

GEMINI

8-Meter Telescopes Project

Gemini's Mirrors - Twin Blanks A Reality



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nited States • United Kingdom • Canada • Chile • Brazil • Argentina

Introduction

Gemini's Mirrors - twin blanks a reality reads our headline, and the front cover shows the loading of the first Gemini blank at the start of its (thankfully) uneventful trans-Atlantic journey to France to begin polishing. The other picture shows the second Gemini blank after it was successfully fused at the Corning plant in Canton, New York. With these two central milestones for the Gemini Project we start our "new look" Gemini Newsletter. With a little over two years now to our first ***"First Light"*** we are going to begin to focus the newsletter more and more on the scientific opportunities the Gemini Telescopes offer its international partnership. To get the ball rolling, after Dick Kurz's *Project Update*, Fred Gillett, our new Project Scientist reviews the Gemini Telescopes from a scientific perspective. Then follow reports from our national Project Offices, an article on Adaptive Optics on Gemini, and a discussion of the thinking and planning going into our Phase II Instrumentation Program.

We hope you like the new format, and that it begins to start you all thinking about what programs you would like to undertake on the Gemini 8-M Telescopes.

Matt Mountain
Project Director

Project Update - June 1996

Construction of the Gemini North and South telescopes has moved forward rapidly in 1996. Foundation work is complete at both Mauna Kea and Cerro Pachon. Bad weather forced the shutdown of site construction activity on Mauna Kea from late December 1995 until April 1996. Fortunately, with their accelerated schedule, San Juan Construction had completed the foundation work needed to start erecting steelwork before the bad weather closed in. Erecting the enclosure base and support facility structural steelwork will be completed at Mauna Kea in July 1996, and at Cerro Pachon in August.

Coast Steel is well along with fabrication of both enclosures. Preassembly of the first enclosure at their plant is underway in preparation for starting erection of the enclosure carousel at Mauna Kea in July 1996. They will install the Cerro Pachon enclosure, once the Mauna Kea enclosure is complete.

The contract for the final piece of the Mauna Kea site construction was awarded to San Juan Construction in May 1996. We have requested proposals for completion of the Cerro Pachon site construction and expect to award that contract by August 1996. The recent accident involving fatalities during construction of the Subaru enclosure on Mauna Kea has focused everyone's attention on safety. We completed a safety review of Gemini construction activities prior to the restart of work on Mauna Kea this spring.

Final fabrication details of the telescope structures were approved in January 1996, and Telas/NFM is well into fabrication. SKF will deliver the telescope hydrostatic bearings in time for preassembly of the first telescope structure at NFM's Le Creusot factory, which will start in August.

Following successful development of processes for sputtering protected silver coatings, contracts have been placed by RGO for the coating chamber vacuum vessels (Process Systems International) and pumping systems (Leybold). At a minimum, the Mauna Kea coating plant will be able to produce aluminum and silver coatings at initial commissioning, and we will be able to easily add silver coating capability to the Cerro Pachon plant.

Turning to the optics, grinding will start this summer at REOSC on the first Gemini primary mirror blank. Corning has fused and plano-generated our second primary mirror blank. It will be slumped to its curved shape in July 1996. In April we awarded the contract for fabrication of the primary mirror cell structures to Telas/NFM. Under this contract, they will also provide facilities to us for assembly and testing of complete mirror cell assemblies at their Le Creusot plant. Fabrication, assembly, and testing of the mirror support system components at RGO in the UK is progressing on a schedule to be available when the mirror cell structure is completed by Telas/NFM.

Development in Tucson of electrical surface heating for the primary mirrors has progressed well through testing of a one-meter prototype. Primary mirror surface heating has now been added to the baseline for the Gemini North and South telescopes.

In February we awarded a contract to produce the Gemini silicon carbide f/16 secondary mirrors to Carl Zeiss. Morton will provide the SiC blanks for Zeiss. The critical design review for the complete secondary mirror assembly, including the Zeiss/Morton mirror, the Lockheed-Martin fast tip/tilt/focus mechanism, as well as the slow positioning and deployable baffle mechanisms designed by the project, will be held in June 1996.

Table 1. Status of Controls Development

Work Package	System Design Review	Preliminary Design Review	Critical Design Review	Alpha Release	Beta Release	Final Release
Principal Systems						
Observatory Control System	▨	▨	▨			
- VUI Simulator	▨	▨	▨	▨	▨	▨
- Control Simulator	▨	▨	▨	▨		
Telescope Control System	▨	▨	Jul-96			
Data Handling System	▨	Jun-96				
Core Instrument Controller	▨	▨	▨			
Interlock Safety System	▨	▨				
Real-Time Systems						
Standard Controller	▨	▨	▨	▨	▨	▨
Mount Control System	▨	▨				
Primary Control System	▨	▨	▨			
Secondary Control System	▨	▨	▨			
Enclosure Control System	▨	▨	▨	▨		
Hydrostatic Bearing System	Jul-96					

In the controls and software area, the work has been divided into principal systems (observatory control, telescope control, data handling, core instrument control, and interlock systems) and real-time systems (standard controller, mount control, primary control, secondary control, enclosure control, and hydrostatic bearing control systems). Table 1 summarizes where we are in the structured development of these Gemini control system elements. Most of the work packages are at the critical design review or prototype level.

In the facility instrumentation, RGO has issued a request for proposals to do the detailed design and manufacture of the acquisition and guiding opto-mechanical assemblies. Proposals are due in June 1996. The initial design review has been completed on the wavefront sensors and detailed design is proceeding in this UK/Canadian collaborative effort. RGO is responsible for integration of the overall acquisition and guiding system. Design of the Cassegrain rotator, cable wrap, and instrument support structure has been completed in Tucson, and proposals requested for fabrication of this hardware. Work on the Gemini adaptive optics system was put on hold at the conceptual design level while a thorough assessment was made of the scientific utility of the initial low-order natural guide star system for the Mauna Kea telescope.

The pace of activity on the scientific instruments is increasing. Preliminary design review for the Gemini multi-object spectrograph was completed in March and detailed design is underway in the UK and Canada. Both the near-infrared imager and spectrograph have passed conceptual design reviews, and are into preliminary design at the University of Hawaii and NOAO, respectively. The conceptual design review of the high resolution optical spectrograph work at University College London is scheduled for Fall 1996. Finally, the

US Gemini Project Office has requested proposals for conceptual design studies of a mid-infrared imager for Gemini.

The third review of the overall Gemini system was successfully completed in March 1996. Looking forward to system integration, testing, and commissioning, staff has been added to the Systems Engineering Group to increase the effort on detailed integration and test planning and interface control. This activity is essential to successfully carrying out the system integration and tests leading to first light at Mauna Kea in December 1998.

-Richard Kurz
Gemini Project Manager

The Gemini North site on Mauna Kea (left) and the Gemini South site on Cerro Pachon (below) in April, 1996

The Gemini 8m Telescopes Project - A Scientific Overview

1. INTRODUCTION

The main scientific theme of the Gemini partnership is observing and understanding the origins and evolution of stars and planetary systems, of galaxies and of the universe itself. To aggressively pursue this theme, four key scientific capabilities have been adopted for the Gemini Telescopes (Gemini Science Requirements, 1994);

1) **Two 8-m diameter telescopes**. One telescope will be located on Mauna Kea, Hawaii, and the other on Cerro Pachon in Chile. All astronomical objects will be accessible to the Gemini telescopes, regardless of their location on the celestial sphere. Both telescopes have been designed to be identical to support scientific programs spanning both hemispheres and to reduce costs.

The principle Gemini optical configuration is a 8-m diameter f/1.8 meniscus primary mirror with a 1.2-m diameter central hole made of Corning ULE^{TM} glass, with a 1.02-m diameter, articulated, SiC secondary mirror with a 0.168-m diameter central hole, providing an F/16 Cassegrain focal plane 4 meters behind the primary mirror. The telescopes have been designed with interchangeable top ends with capacity to accomodate a future f/6 wide field, 45 arcminute, Cassegrain focus.

2) **Superb image quality**. Both Gemini sites have excellent natural seeing. The intent is that the telescopes, including enclosure and tracking effects, will not degrade the best wavefront tilt corrected atmospheric seeing image size by more than 15%. The smallest image sizes will be achieved at near IR wavelengths, where the 2.2μm image quality requirement is for 50% of the encircled energy to fall within a diameter of 0.1 arcseconds, including diffraction.

3) **Versatile Optical/IR capabilities**. The broad scientific goals of the Gemini partnership require the Gemini telescopes to have high throughput from 0.3μm to at least 30μm. Remotely deployable baffles allows the switching between an optimized thermal IR configuration to configurations which support near IR, optical and UV observations. The Cassegrain focal station allows the simultaneous mounting of at least two instruments. In addition, a fibre and (potentially) a direct optical feed to an off-telescope high stability laboratory within the telescope pier will also be available.

4) **Efficient/adaptable Observing.** In order to exploit the best observing conditions for high priority scientific programs, the Gemini facilities will be able to change rapidly between scientific instruments, and support a wide range of observing modes, including both "classical" and queue scheduled observing.

The approaches taken by the Gemini project to achieve these requirements are briefly summarized in the following sections. Further information on the design and performance can be found in the World-Wide-Web version of this newsletter.

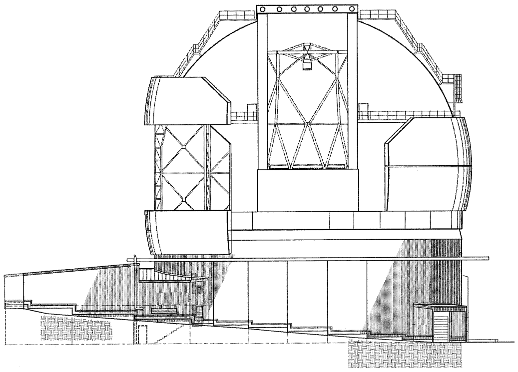


Fig. 1 The Gemini enclosure showing the ventilation gates open on one side and location of the control building.

2. IMAGE QUALITY

Superb image quality is the key scientific requirement of the Gemini telescopes. To deliver natural 0.1 - 0.2 arcsecond near infrared images to the focal plane required that careful attention be paid to every aspect of the facility design. This necessitated a detailed and unique analysis of the entire Gemini system (Mountain et al 1994a) including: water tunnel (Raybould, et al, 1994a) and super-computer (De Young and Charles, 1995) modeling of the wind flow in and around the Gemini enclosure, thermal modeling of the telescope structure and enclosure components, extensive optical and dynamic finite element analysis of the optical system, telescope and enclosure -- which included its foundations and the soil or rock properties of Mauna Kea and Cerro Pachon.

The Enclosure

The enclosure, seen in Figure 1, has large variable ventilation gates so the enclosure chamber can be flushed effectively by the wind or by an active ventilation system during observing. The control building is separated from the unheated enclosure and electronic boxes within the dome are actively cooled to minimize heat input to the chamber. The telescope elevation axis is 20m above ground level, above the turbulent boundary layer (Raybould, et al,1994a).

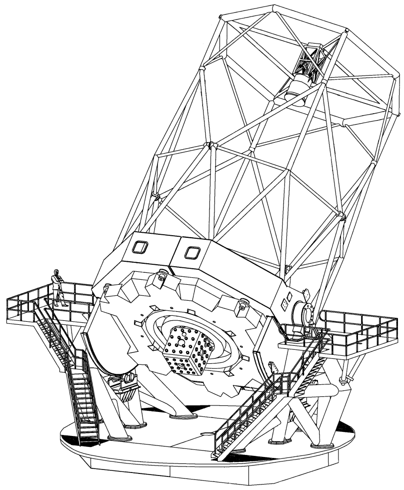
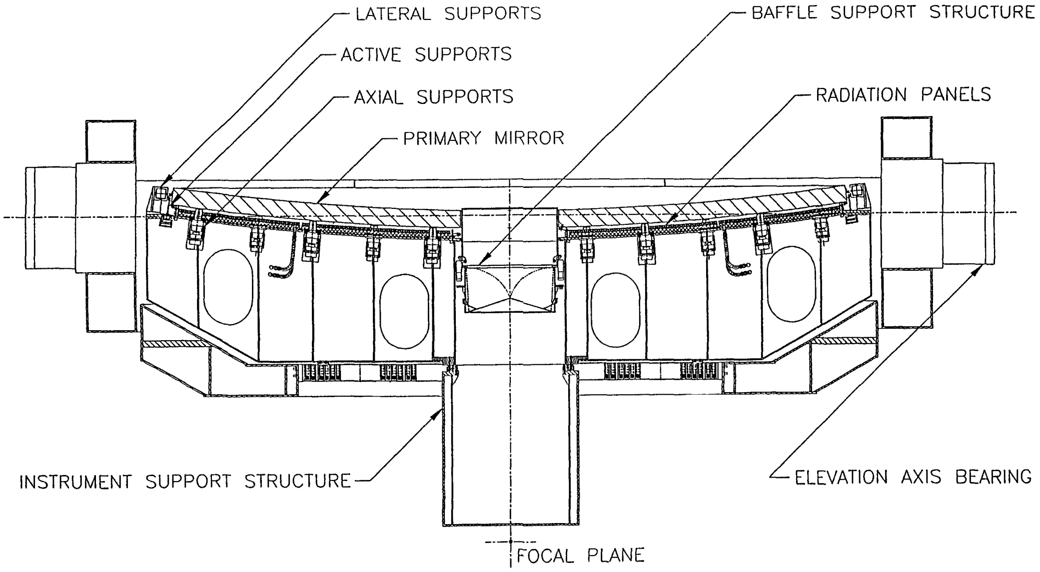


Fig. 2 The Gemini telescope with the Instrument Support structure (ISS) mounted at the Cassegrain focal station.

The Telescope and Optics

The stringent image quality requirements have led to a Cassegrain only telescope (Mountain et al, 1994, Raybould, et al, 1994b), shown in Figure 2. With no Nasmyth foci, the entire telescope structure can be designed to minimize telescope contributions to the final image quality. The structure in front of the primary mirror is optimized to support the secondary mirror assembly, minimizing the thermal mass in front of the primary mirror and

Fig 3. An overview of the primary mirror assembly indicating major components.



cross-section for wind loading. The primary mirror is mounted close to the front surface of the center section for efficient flushing of the mirror surface to reduce primary mirror seeing.

The primary mirror assembly is illustrated in Figure 3. The image quality requirements have led to a new approach to the support and alignment of the meniscus primary mirrors (Stepp and Huang, 1994). Eighty percent of the mirror weight is supported by a uniform air pressure. The remaining twenty percent of the weight is taken by 120 axial supports which provide both passive and active control of the mirror figure and position. Lateral support is provided by 72 passive hydraulic supports arranged around the circumference of the mirror.

The light weight, structured SiC secondary mirror is attached to its assembly at three points (Hansen and Roberts, 1994) shown in Figure 4. This assembly, supported by thin (10mm) vanes from the top end ring, incorporates a positioning unit for precise positioning of the secondary mirror perpendicular to the optical axis, and a rapid tip/tilt, fast focus mechanism to correct both wind shake and atmospheric effects.

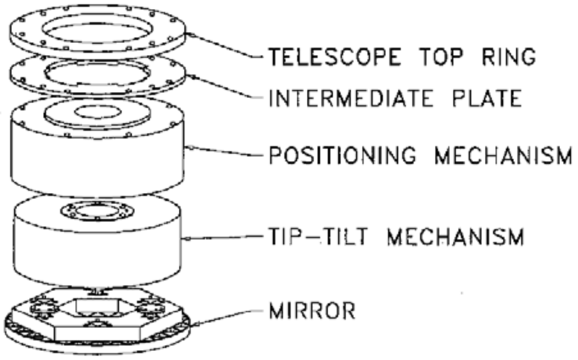


Fig. 4 An exploded view of the secondary mirror assembly.

Thermal control

The intrinsic image quality of a telescope is easily degraded by turbulent mixing of air at different temperatures generated from temperature differentials between the ambient air and components of the telescope and enclosure (see e.g. Racine, etal, 1991). The design of the Gemini telescope and enclosure has been substantially driven by the requirement to minimize these “mirror seeing” and “telescope seeing” effects.

During the day, the enclosure skin is actively ventilated to reduce the solar heat load on the internal enclosure volume. This allows daytime air-conditioning of the enclosure volume so the internal enclosure structure and telescope structure can be preconditioned to near the expected nighttime ambient air temperature at the start of observing. In addition, the external surfaces of the dome and upward looking telescope surfaces are painted with a low emissivity paint to mimimize thermal turbulence from supercooling effects during nighttime observations.

The primary mirror temperature is controlled by two interlinked systems. The primary mirror assembly incorporates a radiation plate between the primary mirror and mirror cell for daytime preconditioning of the bulk mirror temperature at or below that expected at the start of observing. In addtion this system can provide slow control of the bulk mirror temperature during the night. To ensure the mirror surface temperature tracks the nighttime temperature variations with higher fidelity an electrical current is conducted through the reflective coating on the primary mirror, controlling the surface temperature by ohmic heating (Greenhalgh, Stepp, Hansen, 1994). The current flow is adjusted to follow variations in the ambient temperature. Simulations and prototype testing show that the a 1 deg C temperature change in the primary mirror surface can be achieved in about 15 min.

Active figure and alignment control

During the course of an observation, the alignment of the secondary mirror must be maintained to within 2 - 20 microns and the primary mirror surface controlled to within 30 nm rms. A pair of peripheral wavefront sensors (PWFS's), consisting of 8x8 Shack-Hartmann wavefront sensors analyse the incoming wavefront, using reference stars in the peripheral field of view surrounding the science field. The control system then uses these measurements to continuously correct the primary mirror figure and the alignment of the primary and secondary relative to the science focal plane on time scales of a few minutes during an observation. The PWFS's can patrol a 14 arcmin Cassegrain guide field, providing wave front sensing corrections over virtually 100% of the sky..

Tip/tilt and fast focus correction

Rapid image motion or jitter due to atmospheric wavefront tilt and windshake of the telescope and enclosure together with focus changes due to atmosphere and telescope effects, are sensed by low-order wavefront sensors integrated into each instrument. The OIWFS's observe reference stars within the isoplanatic patch around the science FOV by means of pickoff mirrors or dichroic beam splitters. The tip/tilt and focus errors sensed by these On-Instrument wavefront sensors (OIWFS) are corrected by means of small tilts and piston motions of the articulated secondary mirror. The Gemini IR instruments are being designed with infrared sensitive OIWFS's (1-2.5 μm) in order to exploit Gemini's imaging performance in dark cloud regions (Simons, 1995). In addtion, by using IR wavefront sensors we can potentially expect better image motion correction even at the galactic poles,and enable daytime observing.

3. VERSATILE OPTICAL/IR CAPABILITIES

The Gemini telescopes will provide superb image quality from the UV to IR. To scientifically exploit this broad wavelength range without comprimising performance requires that the telescopes and facilities support a number of different configurations.

Optical to IR Baffling

The telescopes are equipped with a fixed chimney baffle mounted from the central hole in the primary mirror, and a three-position remotely deployable secondary baffle mounted on the positioning unit behind the secondary mirror. The optical and UV configuration uses the fully deployed secondary baffle position, about 2 m in diameter, to block direct sky illumination of a 12 arcminute diameter field of view in the telescope focal plane. For the thermal IR configuration this secondary baffle is fully retracted and then set at intermediate positions with deployed diameters of between 1.1 and 1.2 m diameter for near IR observations.

High Reflectivity and Low Emissivity Coatings

The coating plants will need the capability for depositing a variety of mirror coatings. Gemini has undertaken a series of development programs for sputtered Alumimum coatings and for protected Silver (Ag) coatings. The reflectivity of samples produced by these programs is shown in Table 2 compared to the reflectivity requirements and goals for the optical surfaces (Gemini Science Requirements, 1994).

At thermal infrared wavelengths it is not just the reflectivity of the mirrors which is important but also the total telescope emissivity. Both Mauna Kea and Cerro Pachon are very dry sites (with the exception of the Southern Hemisphere site in summer months), with transmission in portions of the atmospheric windows around 2.3, 3.7 and 10μm in excess of 98%. To exploit the correspondingly low atmospheric background emission, the Gemini telescopes IR

Table 2: Al and Ag Sample Reflectivity

	0.33-0.40μm	**0.40-0.70μm**	**0.70-1.1μm**
Bare Al	0.87	0.89	0.90
Bare Ag	0.80	***0.97***	***0.98***
Minimal Protected Ag	0.76	0.95	***0.98***
Protected Ag	0.86	0.92	0.96

Meets Requirements ***Meets Goals***

configuration is designed to have a telescope emissivity less than 4% with a goal of acheiving 2% in the thermal IR beyond 2.27μm. To this end, IR configuration includes thin, 10mm secondary vanes, a pupil stop at the secondary mirror, and small bevels on the secondary mirror. The secondary mirror itself has been designed with a central hole so even in reflection the focal plane "sees" only cold sky in the vicinity of the central primary mirror bore and chimney baffle. Emissivity measurements on bare and protected Silver coatings together with APART analysis of the telescope configuration indicates that with Silver coatings on the primary and secondary mirrors, the Gemini telescope emissivity should approach the goal of 2%. (Dinger, 1993)

Consequently the intent is that Gemini will schedule “Aluminum Semesters” and “Silver Semesters” at both sites, to optimally support UV-Optical programs and Optical-IR programs respectively.

In order to maintain the extremely low telescope emissivity for extended periods of time between mirror recoatings, an effective and frequent (about once per week) in-situ mirror cleaning capability is required. Comparative cleaning tests using CO_2 snow and Excimer lasers have indicated potentially better cleaning performance for a laser cleaning approach (Kimura, Kim, and Balick, 1994). Further cleaning tests on sample Aluminum and bare and protected Silver mirrors are still underway.

Chopping Secondary Mirror

The articulated secondary mirror will be capable of simultaneous tip/tilt compensation and "chopping" at 5 to 10 hz for 10 and 20μm observations. Both capabilities are incorporated into the tip/tilt mechanism supporting the secondary mirror. This mechanism includes an active vibration compensation system to allow the 1m diameter secondary mirror to be “chopped” up to 10Hz without inducing vibrations into the telescope structure, so that the image quality during chopped observations will not be compromised

Cassegrain Instrument Support

The Cassegrain Instrument Support Structure (ISS) (Figure 5) incorporates acquisition and guiding capabilities, the PWFS's, and a science fold mirror for directing the telescope beam to any of the four side-looking insturment ports. The science fold mirror can also be retracted to allow the uplooking instrument port a clean, unimpeded access to the telescope beam for polarimetry, UV and thermal IR instruments. The ISS allows three 2000 kgm science instruments to be mounted simultaneously at the Cassegrain focus. In addition a Calibration Unit and an Adaptive Optics (AO) unit can be mounted on the remaining sidelooking ports. The AO module accesses the sky via a AO feed mirror in the ISS and can then feed, using the science fold mirror, a AO corrected F/16 beam to any instrument mounted on the ISS. The entire Cassegrain assembly rotates to maintain the orientation of scientific instruments with respect to the sky during any observations (Montgomery, Robertson and Wieland, 1994).

4. EFFICIENT/ADAPTABLE OBSERVING

With the stringent image quality and emissivity requirements of the Gemini telescopes, the sensitivity of most observations will be limited solely by the physics of the atmosphere.

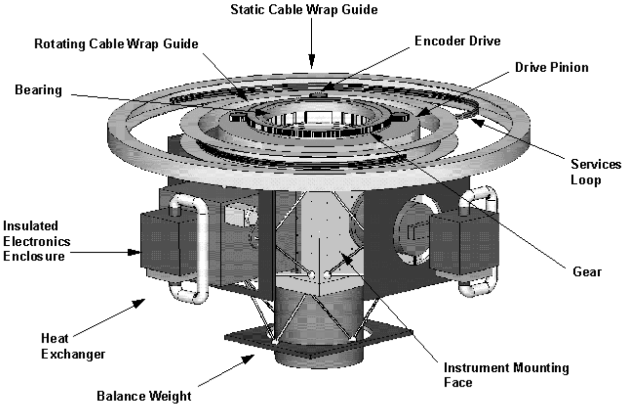


Fig. 5 The Instrument Support Structure(ISS) layout. Instruments can be mounted on the side-looking faces and on the up-looking face of the ISS.

Consequently, the “dynamic range” of delivered image quality and and infrared background will be far greater than we have experience with conventional groundbased telescopes. Observing time will also be at a premium on the Gemini telescopes, especially that time which exploits the unique characteristics of the telescopes and sites. Therefore the observatory operating philosophy will be key to maximizing the scientific productivity of the Gemini telescopes (Mountain et al, 1994b). These facilities will therefore support a range of observing modes; "classical" observing with the astronomer present at the telescope, modes with the astronomer either participating remotely, or more innovative modes (for ground based telescopes) such as queue scheduled observing where observatory staff carry out observations for the astronomer matching the observing conditions to the most appropriate observations. At least 50% of the observing time will be allocated to queue scheduled observations to allow the entire Gemini partnership to scientifically exploit the best conditions. To maximize scientific productivity under changing sky conditions, the observer can readily adapt the facility by changing between mounted instruments during the night by reconfiguration of the control system and secondary baffle and redirecting the science beam to alternative instruments with the science fold mirror. Consequently, as part of the Gemini observing system, efficient observation preparation tools, scheduling and rescheduling tools, environmental monitoring and data quality assessment capabilities will be provided. In addition, the necessary high bandwidth communication links to support remote observing will be available. Gemini will keep a permanent record of observations and ancillary data in perpetuity, sufficient for the future re-creation of the observations and adequate for useful archiving.

Time Allocation

The time allocation process relies on National Project Offices within the partner countries to interface with their communities. Proposals will be solicited semi-annually from the partner communities by the Gemini National Project offices. Within each of the partner countries an appropriate National TAC will rank the proposals into priority-ordered lists for "classical" and queue observations and forward them to Gemini, who will merge the national lists into a preliminary schedule of "classical" time and queue listings, taking into account observation requirements, national shares, instrument availability and engineering support requirements. A single International TAC, made up of representatives from the NTAC's, will review the preliminary schedules and make recommendations for the final schedules. The ITAC will also review the results of past observing periods to ensure fairness and effectiveness of the allocation and observation execution processes.

5. INSTRUMENTATION PROGRAM

To exploit the superb image and low emissivity characteristics of the Gemini telescopes requires a new generation of instruments and detectors. As with the telescopes, new approaches are having to be developed for instrument design, such as extensive use of finite element analysis, active correction of optical flexure, detailed scattering analysis to reduce instrument emissivities and incorporating both optical and IR wavefront sensors into the instruments. All the instruments will be mounted at the Cassegrain focus. on three faces of the ISS. Table 3 lists the instruments that will make up the initial complement at each site (Simons, Robertson and Mountain, 1995).

Adaptive Optics

Initially on Mauna Kea we will be implementing a Natural Guide Star (NGS) Adaptive Optics system, designed for use in the 0.9 to 2.5μm range and capable of delivering images with

Table 3: Initial Scientific Instrumentation

Mauna Kea	Cerro Pachon
◆ Multi-Object Spectrograph	◆ Multi-Object Spectrograph
◆ Near IR Imager	◆ High Resolution Optical Spectrograph
◆ Near IR Spectrograph	
◆ NGS Adaptive Optics	
←Mid IR Imager→	
◆ Shared Instrumentation with UKIRT	◆ Shared Instrumentation with CTIO
↳ Mid-IR Spectrograph	↳ Near IR Spectrograph
	↳ Near IR High-Resolution Spectrograph
	↳ Commissioning IR Imager

Strehl ratios of 0.5 at 1.6μm in median seeing conditions. The corrected f/16 beam can be fed to any instrument port on the ISS. The plate scale and slit sizes for the infrared instruments are chosen to explicitly exploit this capability. In addition we are exploring the use of integral field units for imaging spectroscopy from 0.9-1 micron for the Mauna Kea GMOS instrument.

The Instruments

- The 1-5μm imager will be used for commissioning the Mauna Kea telescope, as well as scientific observations, and will utilize a 1024^2 InSb array, have plate scales of 0.02, 0.05 and 0.11"/pixel for use with and without AO, and very low internal instrument background, consistent with the low telescope emissivity.
- The 1-5μm spectrograph for Mauna Kea is also based on use of a 1024^2 InSb array, will provide spectral resolutions of about 2000 and 8000, two plate scales (0.05"/pixel and 0.15"/pixel), cross dispersion capability, and option for an integral field module.
- There will be two Multi-Object spectrographs (MOS) operating over the 0.36-1.1μm range, one for Mauna Kea, with coatings optimized for red performance, and one for Cerro Pachon, with coatings optimized for blue performance. Each incorporates three 2kx4k CCD arrays, an image scale of 0.08"/pixel, spectral resolution of up to 10,000 and an integral field module with options for extending wavelength coverage to 1.8μm and additional integral field modules. The MOS's also include an imaging mode, primarily to support definition of the multi-slit masks.
- The 8-30μm imager will initially be deployed at Mauna Kea and will be available for use at first light on Cerro Pachon. It will utilize at ~256x256 Si:As IBC array, a pixel scale of < 0.13"/pixel, and an internal instrument background consistent with the low telescope emissivity.
- The High Resolution Optical Spectrograph (HROS) will be designed as a Cassegrain instrument on Gemini South and will use active flexure compensation to maintain high stability. The highest priority is for this instrument's throughput, particularly in the UV. The instrument will use two 2kx4k CCD arrays, and have resolutions of 50,000 and 120,000.
- The commissioning instrument for the Cerro Pachon telescope will be a 1-5μm imager borrowed from CTIO.

Shared Instrumentation

Because of the limited budget available for the initial instrumentation, Gemini is exploring sharing instruments with UKIRT (MICHELLE, a mid IR spectrometer/imager) and with CTIO (Phoenix, a 1-5μm high resolution, R=100,000 spectrometer).

Development Program

The broad instrumentation capabilities will permit a rapid scientific exploitation of the Gemini facilities. Futhermore, Gemini will have an ongoing instrument development program as it enters its operations phase that will serve to enhance and upgrade the initial instrumentation and provide next-generation instruments. This program is discussed further in Doug Simon's article later in this newsletter.

-Fred Gillett
- Project Scientist
-Matt Mountain
- Project Director

Reports from the National Project Offices

Canadian Gemini Project Office

Our principal focus over the last few months has been on the Gemini Multi-Object Spectrograph (GMOS) and the Gemini Adaptive Optics System (GAOS).

GMOS is a collaboration between Dominion Astrophysical Observatory and two groups in the UK; Royal Observatory Edinburgh and University of Durham. This international collaboration has enabled us to assemble a very strong team. In Canada, the efforts are lead by Rick Murowinski, David Crampton and Tim Davidge. The UK counterparts are Phil Williams, Roger Davies and Jeremy Allington-Smith. The basic specifications for GMOS have been described in previous editions of this Newsletter. The design work is now well advanced, and a very successful Preliminary Design Review was held at DAO in late March. Additionally, GMOS will be equipped with Integral Field Units, which will provide unique two-dimensional spectroscopic capability.

Under the leadership of René Racine and Glen Herriot, we developed a conceptual design for **GAOS** last year which was based on the use of curvature wavefront sensing. This technology is also used in the CFHT Adaptive Optics Bonnette (PUEO) and in the system being developed for the Subaru 8-m telescope. The review committee recommended that we use Shack-Hartmann wavefront sensing, which is used in many other systems. The issues surrounding this choice are quite complex. In discussions with the IGPO early this year, we came to a clearer understanding of the role that GAOS will play on the Gemini telescopes.

Unlike many telescopes, Gemini will have a fast tip-tilt-focus secondary mirror which can correct the lowest order atmospheric aberrations and wind shake, over a wide field of view and with no penalties on throughput or emissivity. In addition, Gemini has an active optics system which will remove most low-order aberrations of the primary mirror. Thus GAOS would only be used when higher order correction is required, and when one is willing to accept the observational constraints of using it. Additionally, there are a number of errors in the telescope optics and the spectrograph or camera optics which cannot be corrected by GAOS. As a result, the required order of correction for GAOS is higher than we had assumed. To reach the required order of correction we will need to use a Shack-Hartmann sensor.

A number of questions had been raised about the scientific value of GAOS so, at the urging of IGPO, Simon Morris, Tim Davidge and several others undertook an intensive quantitative study of the science case for GAOS. We do not believe this has been done for any other astronomical adaptive optics system, and we are quite proud of the results, which show that there is indeed a good science to be done with GAOS. A summary of this study follows. The complete study is available in postscript form from *ftp.dao.nrc.ca*, in the directory *pub/staff/slm/ao_sjust/ao_sjust_rev5.tar*. Alternatively, copies are available from Simon Morris at DAO.

Last fall, René Racine retired as AO scientist, and Gordon Walker has assumed this role on an interim basis. We are very grateful to René for all the help he has given us over a number of years.

Work on GAOS is currently suspended, pending the outcome of the investigation of the science cases, and because of budgetary uncertainties. With the science case now made, we are hopeful that the budgetary uncertainties will be resolved soon and that we can move forward with the GAOS project.

-Andy Woodsworth

Canadian Gemini Project Manager

Argentinian Gemini Project Office

A National Gemini Office is being set up at the Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, 1900 La Plata. The Coordinator is Jorge Sahade assisted by Nidia Morrell. Dr. Emilio Lapasset will serve as Project Scientist and Dr. Hugo Levato as Project Manager.

A Scientific Advisory Committee has been integrated with representatives of the different astronomical institutions in Argentina, as follows:

- Edmundo Marcelo Arnal (IAR),
- Carlos Natale Francile (OAFA, San Juan),
- Emilio Lapasset Gomar (Córdoba)
- Nidia Irene Morrell (La Plata)
- Marta Rovira (IAFE).

The Office is considering a plan for the formation of human resources and for outreach activities and is considering the installation at La Plata of a center for remote observing by the Mercosur astronomers.

-Jorge Sahade
-Argentinian Gemini Coordinator

Science Drivers for Adaptive Optics on Gemini North

We examine topics, ranging from planetary searches to cosmology, that require adaptive optics (AO) and which we believe will represent major legacies of Gemini. Our goal is to establish a framework of science against which proposed AO technical solutions and performance tradeoffs may be judged. At the time of writing, little science has been done with AO systems, and extant or planned systems span an enormous range of technical implementations and cost. However, it is clear that AO will play a major role in astronomy of the next decade. Based upon extensive experience with relevant IR, CFHT and HST programs, we estimate the Strehl ratio, field size, target magnitudes, and wavelengths required for 10 subjects. Eight topics discussed in an appendix illustrate in more detail the types of science that AO on Gemini can enable.

Our goal is to provide a science framework to determine required instrument performance. It is not always possible to quantify all relevant factors in the complex web of science tradeoffs, especially when performance projections of higher-order AO systems currently rely heavily on modelling, rather than on actual astronomical experience. Thus, discussions of AO are difficult to isolate completely from implementation strategies, including budget constraints.

Where necessary for more quantitative understanding and/or projections, we have adopted as assumptions in this version the current baseline parameters for Gemini's natural guide star AO system, which include:

- 12x12 Shack-Hartmann wave front sensors,
- 3 electron readout noise CCDs, and
- Conjugation of the deformable mirror to altitude

For the detailed science programs, we attempt to indicate what we can hope to achieve with the Gemini AO system. Since the data analysis is as crucial to producing the science as the hardware implementation, we also comment upon such issues in these cases. We assume that the suite of instruments on Gemini North will consist only of an IR camera with pixel scales of 0.02 arcsec, 0.05 arcsec and 0.12 arcsec and a field-of-view of 20-120 arcsec; an IR spectrograph with a pixel scale of 0.05 arcsec and a 50 arcsec field-of-view; and GMOS, an optical multi-object spectrograph, with a pixel scale of 0.08 arcsec and a 5 arcmin field-of-view. GMOS will also have an Integral Field Unit (IFU) with 0.2 arcsec lenslets and a 10 arcsec field-of-view, with correspondingly smaller field-of-view. An extension of the GMOS to allow operation in the J and H band is also being discussed. The near IR spectrograph may have an IFU with 0.05 arcsec lenslets

We identify capabilities that are essential for tackling the science programs, and criteria for assessing the GAOS are discussed.

The conclusions reached from our broad assessment of the science are:

- A Strehl ratio of 0.1 - 0.8 in the 0.85-2.5 micron range will accomplish a scientifically compelling suite of programs;
- Queue scheduling is essential for efficient use of the AO system, as many programs (particularly those focussing on wavelengths shortward of the H-band) will only be possible during conditions of good seeing;
- A field size of 20-30 arcsec diameter within which the Strehl ratio is above 0.5 in K appears to be well-matched to most of the science goals;

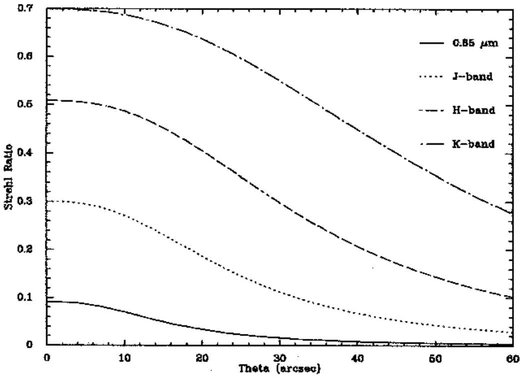


Figure 6. Dependence on expected Strehl ratio delivered to the near IR imager focal plane, in 10% best seeing, at a zenith distance of 45^o.

- Fortuitously, many science goals are within reach for Strehls between 0.1 and 0.5, since higher Strehls will probably only occasionally be available with bright on-axis guide stars and good seeing conditions;
- A useful fiducial Strehl value is that needed to produce a S/N gain of a factor 2 in a small aperture compared to that achieved without AO, but with correction of tip/tilt and focus. For several projects listed here though, the additional information available in high spatial resolution may outweigh simple S/N arguments.
- The small number of simulations performed to date emphasize the need for good sampling to take advantage of Strehl ratios above 0.2.

Providing that the implemented natural guide star Gemini AO system meets the current performance goals, it appears that exciting, legacy science will be enabled.

-Simon Morris, Tim Davidge, John Hutchings, Peter Stetson, Daniel Durand, Dennis Crabtree, and Pat Cote

Gemini Phase II Instrumentation

The Project is beginning to formulate plans for Gemini's Phase II instrumentation program. In general the emphasis on Phase I instruments has been to develop the so-called "work horse" instruments that are expected to be used across a broad range of observations. These instruments include optical and infrared imagers and spectrographs (GMOS, NIRI, and NIRS). Phase I instruments have been described in previous Newsletters (June 1995) and the Gemini Web page. Due to funding constraints within the Phase I program, not all desirable options could be included in each instrument and the Project has worked closely with the Phase I instrument builders to assure that clear upgrade paths exist to support retrofits of upgrades. The Phase II instrument program will therefore consist of a combination of new instruments and upgrades to Phase I instruments. This blend of new Phase II instruments and upgrades to Phase I instruments is a cost effective approach to delivering maximum capability in the overall instrument program while working within a cost-constrained budget. Though there is duplication between some of the Gemini N/S "work horse" instruments, in general the Phase II instruments should be directed at either gaps in the capabilities of the Phase I instruments or targeted at unique capabilities that the Gemini telescopes offer for instrumentation.

Considerable resources are being invested in the Gemini telescopes' abilities to achieve exquisite image quality, high throughput, and low emissivity, and all instruments should in general take advantage of these facets of the telescopes. These design drivers are reflected in a number of ways within the observatories including:

∗ **Enclosure** - adjustable ventilation, daytime air conditioning, etc.
∗ **Telescope Structure** - minimal thermal mass above the primary, low wind buffeting cross section, etc.
∗ **Primary Mirror Temperature** - backside substrate cooling, planned surface heating
∗ **Coatings** - high performance silver and aluminum available at both sites on primary and secondary
∗ **Cleaning Program** - extensive mirror cleaning capabilities built into facilities (laser and CO_2 snow under consideration)
∗ **Facility Wavefront Sensing & Active Correction** - adaptive optics, on-instrument, and peripheral field sensors
∗ **Queue Scheduled Observations** - at least 50% of observations will be queued to match conditions with proposals

All of these considerations reflect the Project's efforts to build telescopes that are fundamentally limited by the physics of the atmosphere and the sites. This in turn drives the instrument designs if they are to exploit the unique observing platform Gemini offers. For example, near-infrared wavefront sensors will be incorporated into the near-infrared imager and spectrograph to support good tip/tilt/focus corrections *even in dark clouds*, and the near-infrared instruments are being designed to limit their contribution to the background to <1% effective emissivity to preserve the ~2% emissivity of the telescope.

Table 4 lists the Phase I instrument package, planned shared instruments, possible upgrades to Phase I instruments and some possible Phase II (new) instruments. It should be noted that the upgrades and suggested Phase II instruments are only *illustrative* of what might be included in a Phase II program. *The Project seeks input from the Gemini community through the various National Project Offices while compiling the Phase II instrument complement.* The rationale for some of the proposed upgrades listed in Table 4 includes a 2x2k format array for the NIRI to expand the imaged adaptive optics field, which now is ~20" across with the fine (0.02") plate scale. Also, a near-infrared mode (out to

~1.8 µm) for GMOS could be achieved by installing a Hg:Cd:Te array or mosaic in the baseline GMOS, providing unique multi-object near-infrared spectroscopic capabilities.

As mentioned before, ideally new Phase II instruments should take advantage of unique telescope design features to provide new capabilities that other telescope/instrument combinations may not be able to achieve as well. One such example, listed in Table 4, is a near-infrared coronagraph. If such an instrument is pursued, optimized designs like those described in Nakajima *et al*. (1994, “Planet Detectability by an Adaptive Optics Stellar Coronagraph”, *Ap. J.*, **425**, pp. 348-357) might offer significant advantages over common past designs. For example, factors that play important roles in the performance of a coronagraph include:

- Smoothness of the primary mirror
- High performance atmospheric compensation
- Thin secondary support vanes
- Low obscuration ratio
- Overall throughput

For a coronagraph it is crucial that sources of scattered light be cut to a minimum in order to maximize contrast ratios. Certainly one of the most important elements in the optical path that effects scattering is the primary mirror. Gemini has already set rigorous specifications for the smoothness of its primary mirrors and the elimination of harmonic scattering. Between the primary mirror polishing specification and the ability to actively control its surface figure, it should be possible to achieve significantly lower scattered light contamination in a Gemini-mounted coronagraph than is currently achieved with coronagraphs on most 3-4 m class telescopes. The small obscuration ratio and thin vanes used to support the secondary mirror will also lead to reduced diffraction effects. Of course telescope throughput boosts the performance of all instrumentation, and a coronagraph is no exception. The high reflectivity coatings used in the Gemini telescope, together with the planned mirror cleaning schedule, will certainly boost the performance of a coronagraph in terms of throughput and scattering. All of these design features make the Gemini telescopes fairly natural platforms for a high performance coronagraph.

Table 4 - The Phase I and possible Phase II instruments and upgrades are listed. Phase I baseline instruments budgeted within the construction fund are in bold while possible shared instruments with either UKIRT in Hawaii or CTIO in Chile are underlined. Possible Phase II instruments are shown in italic.

Mauna Kea		Cerro Pachon	
Instrument	Possible Upgrade	Instrument	Possible Upgrade
Near-infrared Imager	2x2k array	**GMOS**	High-res OIWFS
			High-res. IFU
Near-infrared Spectro.	IFU		
	Cross Disperser	**HROS**	High Stability Lab
		Near-infrared Imager	
GMOS	Near-IR Mode		
	High-res. OIWFS	Near-infrared Spectro.	IFU
	High-res. IFU		Cross Disperser
8-30 µm Spect. (MICHELLE)		**8-30 µm Imager (N/S)**	
NGS AO System	Laser Upgrade	*LGS AO System*	
Near-infrared Coronagraph (N/S)		*CCD Dev (N/S)*	
		Phoenix	

Beyond the telescope properties, there are key aspects of the masks used in a coronagraph that impact performance. To date, most coronagraphs on astronomical telescopes have used conventional hard or opaque masks in the focal plane of the telescope to block light from a bright source. The main problem with using an opaque field mask is that light diffracts around its sharp edge, which then scatters into the periphery of the field of view and leads to the formation of a bright halo. Finding faint objects in this halo can be complicated. In the pupil plane of the coronagraph this effect is manifest as significant amounts of flux at all spatial frequencies passed by the pupil, hence filtering the unwanted scattered light in the pupil plane is difficult. By using a semi-transparent aluminized mask though, performance gains can be achieved in several ways. First, if the mask is placed forward of the adaptive optics unit in the telescope's focal plane, the same bright star that is being observed as a science target can also be used for correction, hence unwanted light is reflected back out of the telescope on-axis well forward of the optical train and adaptive optics performance is maximized since anisoplanatism is nearly eliminated. The optimal location of such a reflective mask is a balance between a number of competing factors, including its position with respect to the deformable mirror and wavefront sensor, and its location in the Gemini AO/telescope environment needs careful analysis, but in general moving it forward in the overall optical train minimizes scattering, which tends to dominate coronagraphic performance. Second, information is preserved right down to the central star with a semi-transparent mask, which is often where astrophysically interesting targets lie. Typically opaque masks measuring many arcseconds in diameter must be used to achieve adequate contrast ratios, which eliminates *all* information immediately surrounding the central star. Third, unwanted high frequency scattering is eliminated since no sharp edge is used in the apodized mask, which has a slow Gaussian reflectivity roll-off. Fourth, residual unwanted spatial frequencies are easier to filter in the pupil plane by using an annular pupil mask that selectively eliminates unwanted frequency

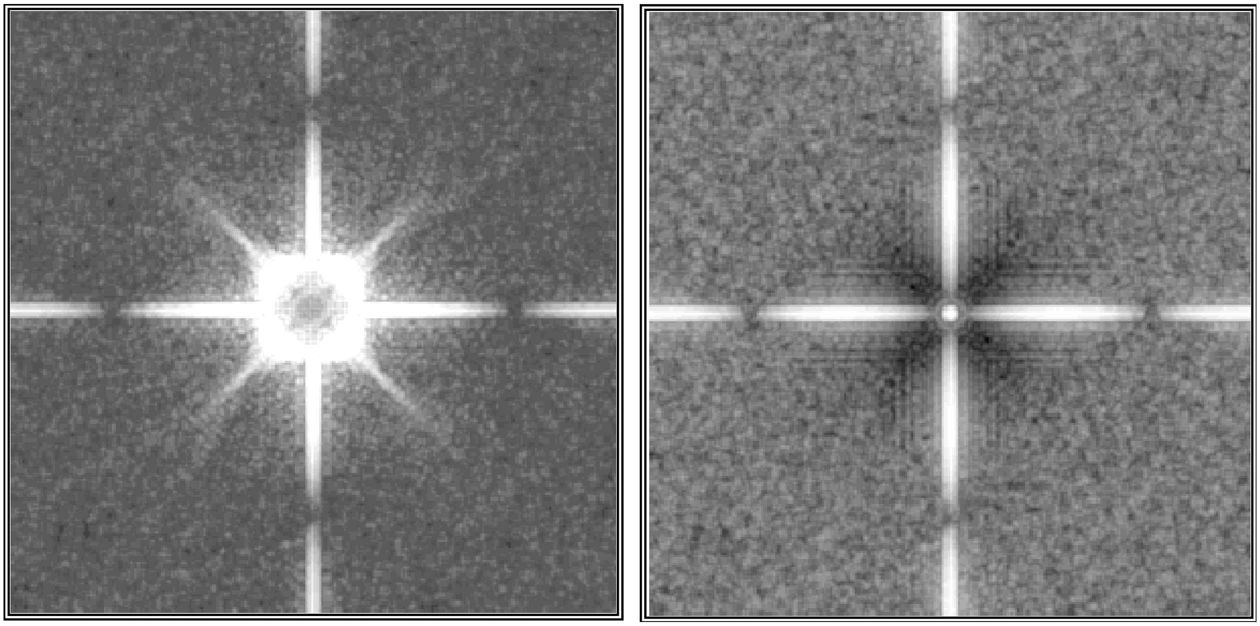


Figure 7 - Simulated coronagraphic images using a conventional occulting mask (left) and a semi-transparent apodized mask with a Gaussian roll-off (right). Diffraction spikes from the secondary mirror support vanes are evident in both images. An opaque mask leads to a bright halo and loss of information in the field surrounding the occulting mask, which is often where the most interesting discoveries lie. In contrast an apodized semitransparent mask preserves spatial information across the entire field of view.

terms. These factors are illustrated in Figure 7 which shows synthetic images made with a conventional (hard mask) and next-generation (apodized mask) coronagraphic model under development within the IGPO. If a coronagraph is built for Gemini there are clearly a number of techniques for optimizing its performance. What is most important is that such an instrument be designed to fully exploit the telescopes which, as explained above, should be effective coronagraphic platforms.

Finally, it is urged that in order to keep the Gemini user community on the leading edge of astronomical research, next-generation instruments should include state-of-the-art technology in optics, electronics, sensing, etc. The previously mentioned optimized coronagraph is but one example of how instrumentation technology and the Gemini telescopes can be married to yield a powerful new capability. The pace of technical developments in fields that can support astronomy is staggering and instrument builders will be challenged to incorporate the latest in optics and electronics to assure Gemini users of effective research tools in an increasingly competitive era of large telescopes. For example, if the recent spectacular images of the "pillars" in M16 with HST emerged after much of the Phase II instrument program outlined in Table 4 were built, Gemini users would have at their disposal a wealth of instruments to effectively *dissect* these peculiar star formation regions and extract the underlying physics of the pillars (see back cover). Specifically, it would be possible to follow-up on the HST imaging with 10 µm imaging of the pillars to identify embedded proto-stars. From there, high resolution near-infrared imaging might be used with a Gemini-South based adaptive optics system to reveal the type of bipolar outflows that are so often associated with forming stars. The integral field unit in the near-infrared spectrograph may then be used to explore the dynamics of the gas outflows surrounding the proto-star. The near-infrared coronagraph could then be used explore the phase space in the immediate environment of proto-star, perhaps leading to the detection of a faint substellar companion. Finally, 0.1" slits could be used with the combination of the adaptive optics system and near-infrared spectrograph to isolate flux from the primary and its faint nearby companion, leading to the spectrum of forming substellar object - no small feat in current ground based astronomy. Clearly such a sequence of observations relies on a fortuitous set of targets, but the Phase II instrument capabilities illustrated by such a hypothetical series of observations, and the ability to probe complex regions at a variety of wavelengths and spatial scales, will hopefully emerge as we define and design the next generation of instruments for Gemini.

- D. Simons
-Assoc. Project Scientist for Instrumentation
- F. Gillett
-Project Scientist

Don't forget to check out
the Gemini Project's
World-Wide-Web site, at
http://www.gemini.edu/!

The AURA Corporate Office
also now has a site on the
World-Wide-Web;
check it out at
http://www.aura-astronomy.org/!

Released Technical Documentation

The following technical documents have been published by the Gemini Project since the last edition of the Gemini Newsletter (December 1995). Copies of these and other publications are available on request by contacting the Gemini Project Documentation Coordinator at the project address, or by e-mailing *rkneale@gemini.edu*. Document numbers are listed in parentheses.

- Numerical Simulation of Airflow over Potential Telescope Sites. DeYoung, December 1995. (RPT-PS-G0068)
- Gemini Document/Drawing Control Plan, R2.0. Kneale/Oschmann, January 1996. (PG-S-G0002)
- Gemini Acronym Glossary, R1.1. Kneale, March 1996. (PG-S-G0008)
- System Review #3 Presentations. Kurz et. al., March 1996. (REV-S-G0061)
- Gemini Telescopes Project (IAU Montevideo). Gillett, March 1996. (RPT-PS-G0064)
- The Gemini Instrumentation Program. Gillett, March 1996. (RPT-PS-G0065)
- Scientific Perspectives on Gemini Data Reduction. Puxley, March 1996. (TN-PS-G0039)
- Functional Specification, f/16 Secondary Mirror Tilt System, Rev. B. Roberts, April 1996. (SPE-O-G0039

  Design Requirements Document, M2 Positioning Mechanism Suspension Bearings. Roberts, April 1996. (SPE-O-G0060)

Staff Changes at Gemini

A number of changes have ocurred in the project organization. Figure 8 shows the current Gemini project organization. Phil Puxley has joined the team as Associate Project Scientist for Operations and Doug Simons has become Associate Project Scientist for Instrumentation. David Robertson, Instrumentation Group manager, resigned to return to the UK. We have combined the Controls and Instrumentation Groups, under Rick McGonegal. We would also like to welcome Dick Heinrich as the new Employee Relations Manager. Earl Pearson, Gemini Chief Engineer, retired at the end of January 1996.

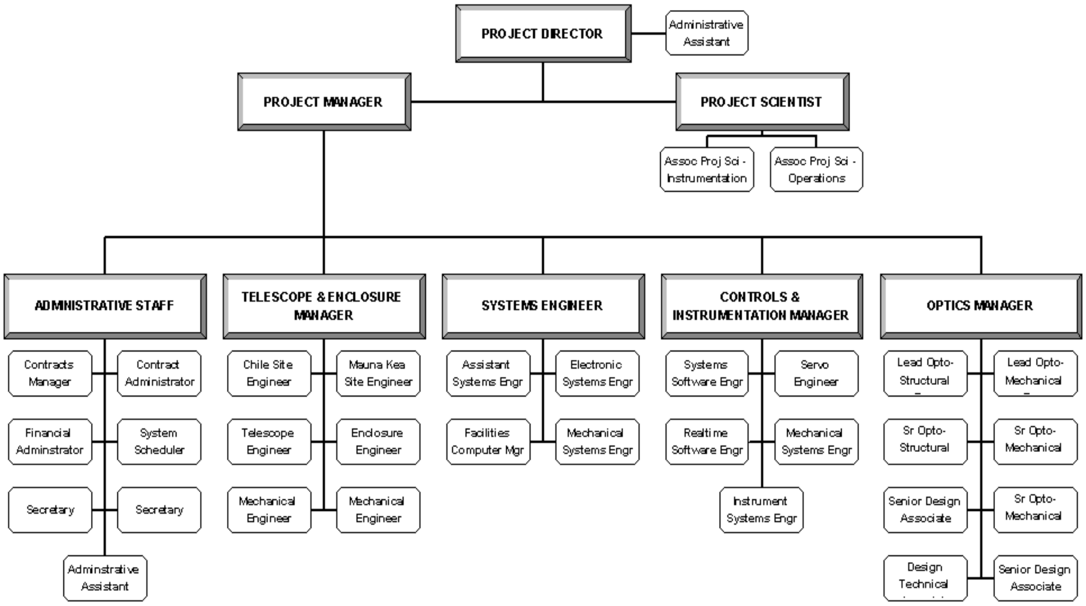
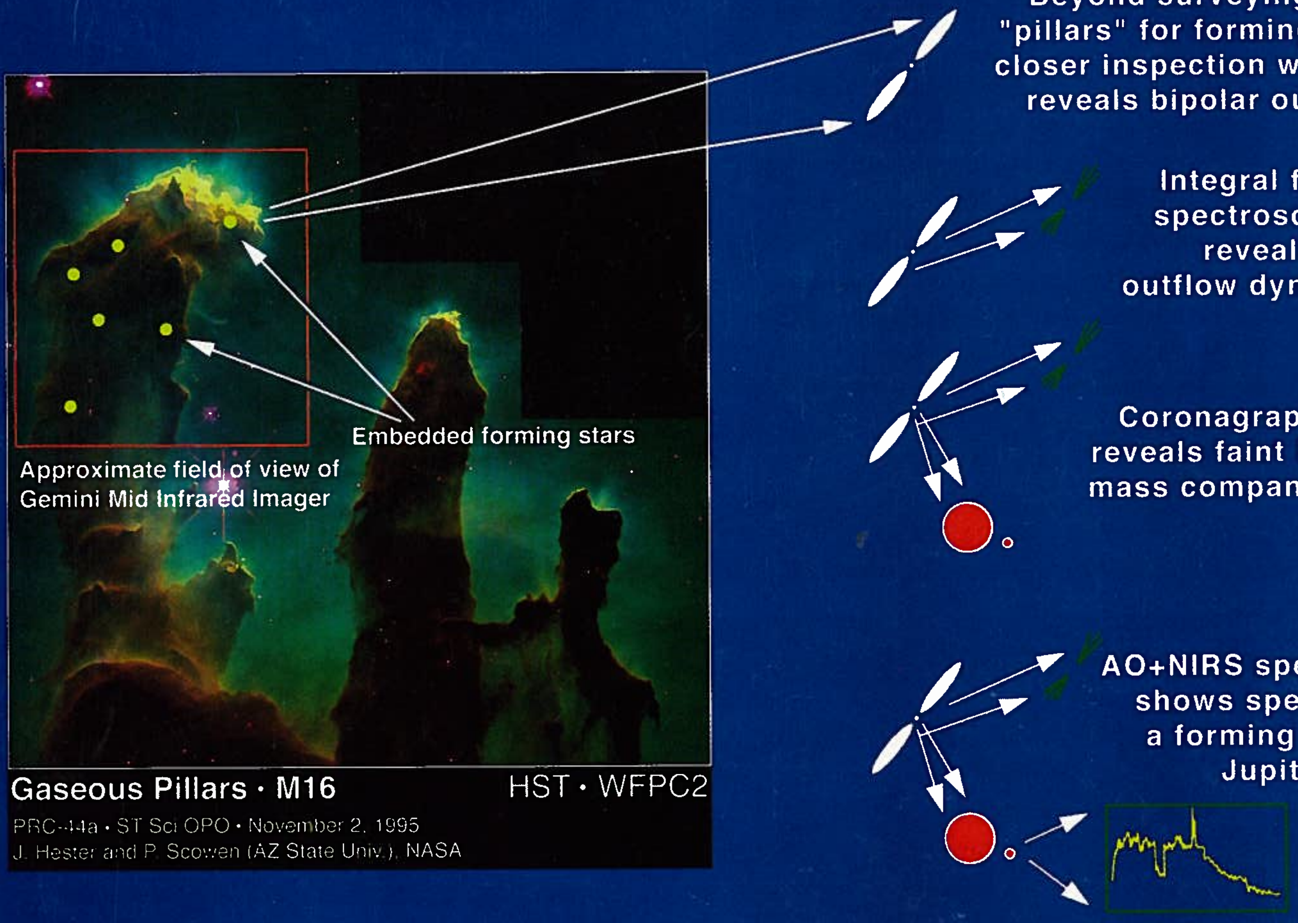


Figure 8. International Gemini Project Office (IGPO) Organization - February 1996

Dissecting M16 Pillars with Gemini
(A Hypothetical Observation)



Gaseous Pillars · M16 HST · WFPC2
PRC-44a · ST Sci OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA

Beyond surveying M16 "pillars" for forming stars, closer inspection with NIRI reveals bipolar outflow

Integral field spectroscopy reveals outflow dynamics

Coronagraph reveals faint low mass companion

AO+NIRS spectroscopy shows spectrum of a forming "super-Jupiter"

GEMINI

8 - Meter Telescope Project

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

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