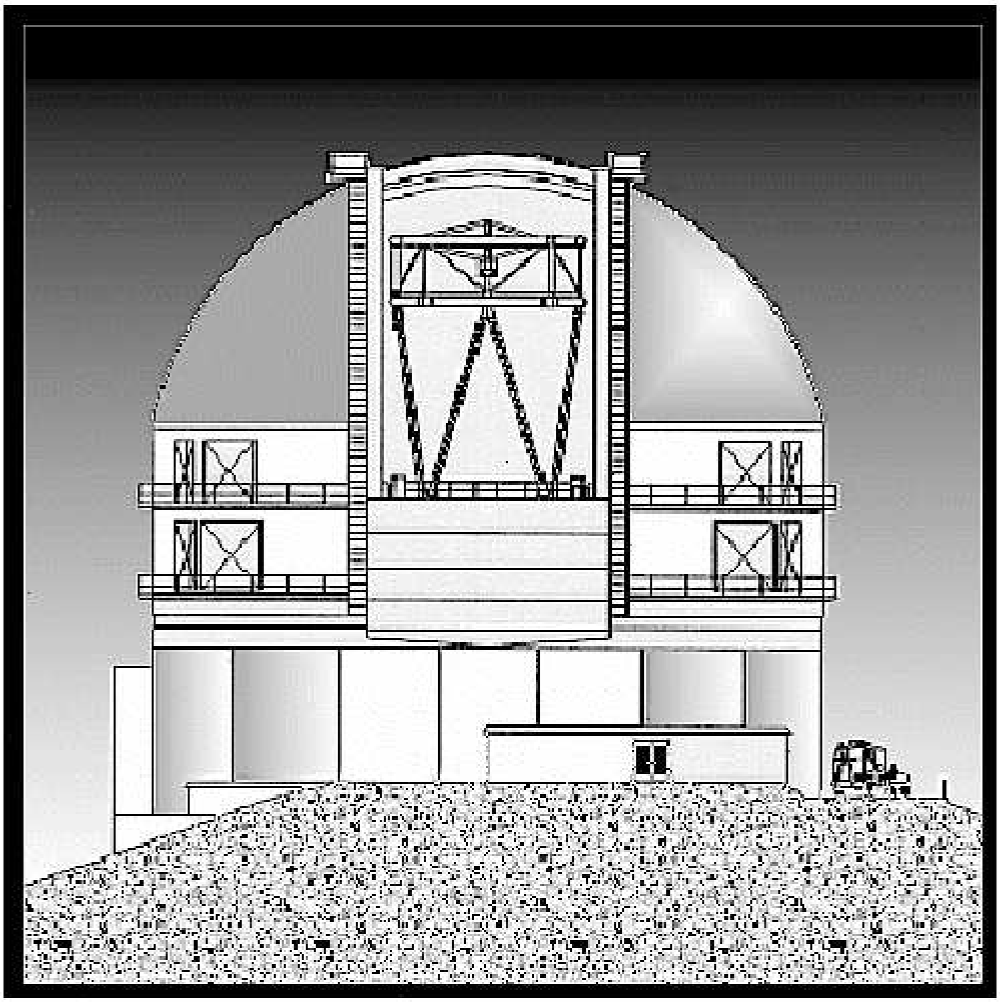
GEMINI
8-M Telescopes
Project

RPT-PS-G0064

The Gemini Telescopes Project



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ABSTRACT

The Gemini Telescopes Project is an international partnership of the U.S., U.K., Canada, Chile, Argentina, and Brazil to build two telescopes, one in the northern hemisphere and one in the south. The telescopes will achieve an unprecedented combination of light-gathering power and image quality over the infrared, optical and ultraviolet spectral regions observable from the ground. The facilities are intended to exploit the best natural observing conditions at the sites to carry out a broad range of astronomical research programs undertaken by the National communities of the partner countries. First light on Gemini-North is scheduled for 1998 and for Gemini-south in the year 2000, with handover to operations in 2000 and 2001 respectively.

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. The two telescopes are identical in design to provide similar performance in programs spanning both hemispheres and to reduce costs.

The optics configuration for the Gemini telescopes is that of a 8-m diameter F/1.8 primary mirror with a 1.2 m diameter central hole made of Corning ULE^{TM} glass, together 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 are designed for interchangeable front ends with capacity to accomodate a future F/6 wide field cassegrain configuration.

2) Superb image quality. Both Gemini sites offer excellent seeing conditions and the intent is that the telescopes, including enclosure and tracking effects, degrade the best wavefront tilt corrected atmospheric seeing image size by less than 15%. The minimum image sizes will be achieved at near IR wavelengths, and the resulting 2.2µm image quality requirement is 50% encircled energy within a diameter of 0.1 arcsec, 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. This includes an optimized IR configuration with remotely switchable baffling for both near IR and optical observations. A cassegrain focal station that permits simultaneous mounting of at least two instruments, and a fibre and potentially a direct optical feed to an off-telescope high stability instrument location within the telescope pier will be available.

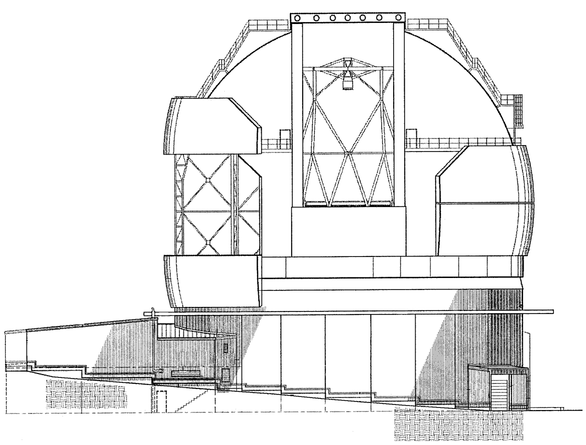
4) Efficient/adaptable Observing. In order to exploit the best observing conditions to do high priority scientific observations, the Gemini facilities will be able to change rapidly between scientific instruments, and support a wide range of observing modes, including both "classical" and queue observing.

In the following sections, the approaches adopted by the Gemini project to achieve these requirments are briefly summarized. Further information on the design and performance can be found in the associated references.

2. IMAGE QUALITY

Achieving the image quality requires careful attention to every aspect of the facility design, including water tunnel (Raybould, etal, 1994a) and super-computer (De Young and Charles, 1995) modeling of the flow in and around the Gemini enclosure, thermal modeling of the telescope and enclosure components and extensive optical and finite element analysis of the telescope structure and optical system.

The enclosure, 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).



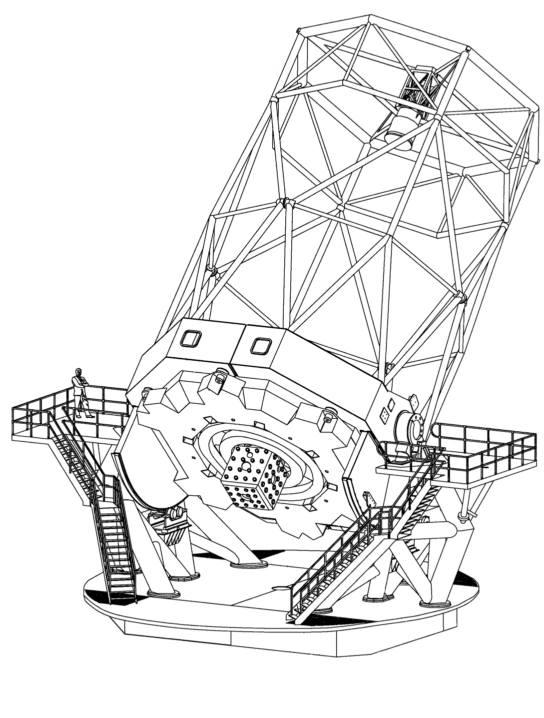


Fig. 1 (above) The Gemini enclosure showing the ventilation gates open on one side and location of the control building.

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

The stringent image quality requirements have led to a Cassegrain only telescope design (Raybould, etal,1994b), shown in Figure 2. With no Nasmyth foci, the design has been optimized 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 while minimizing the cross-section for wind loading, while 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 primary mirror (Stepp and Huang, 1994). It is supported by 120 axial supports with both passive and active components together with a uniform air pressure support. Lateral support is provided by 72 passive hydraulic supports arranged around the circumference of the mirror.

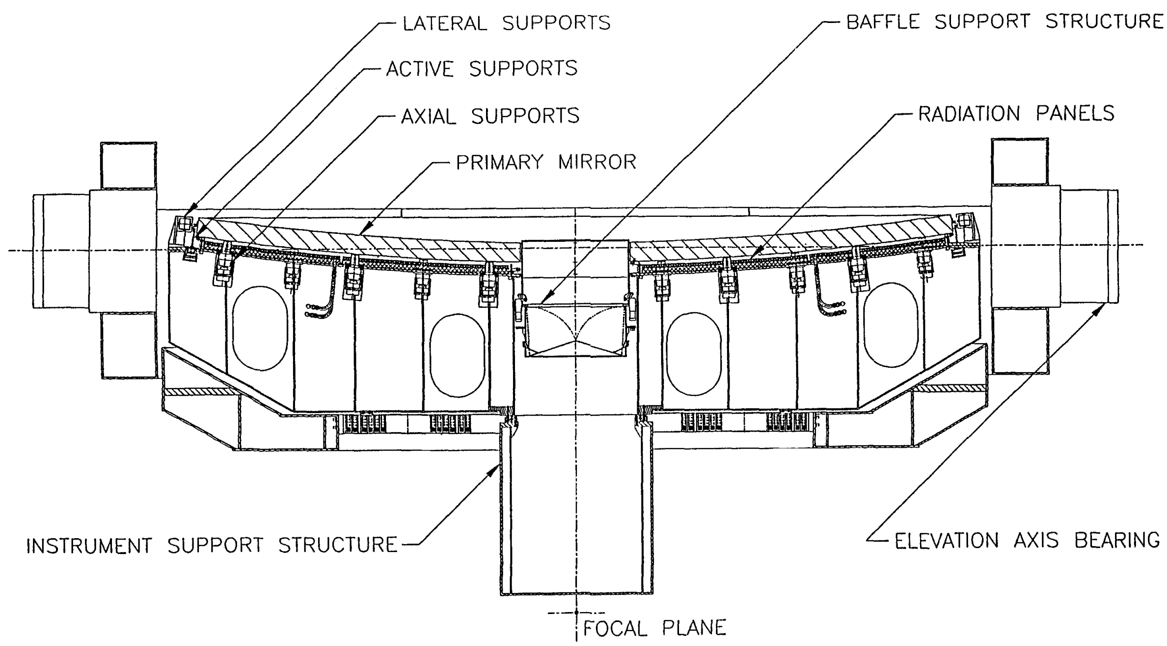


Fig. 3 An overview of the primary mirror assembly indicating major components.

The secondary assembly, shown in Figure 4, includes a positioning unit for precise positioning of the secondary mirror perpendicular to the optical axis, and a tip/tilt mechanism with rapid focus and two axis tilting capability. The secondary mirror is attached to the tip/tilt mechanism at three points (Hansen and Roberts, 1994).

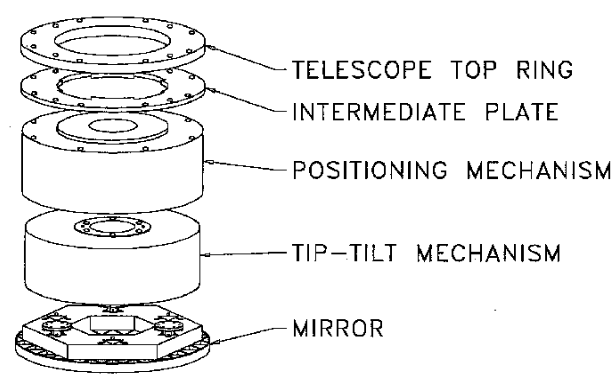


Fig. 4 An exploded view of the secondary mirror assembly.

Thermal control

The intrinsic image quality of a telescope is easily degraded by turbulent mixing of air at different temperatures resulting 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 effects.

During the day, the enclosure skin is actively ventilated to reduce the solar heat load on the internal enclosure volume, allowing the internal enclosure structure and telescope structure to be preconditioned to near the nightime ambient air temperature by daytime air-conditioning of the enclosure volume. In addition, the external surfaces of the dome and upward looking telescope surfaces are painted with a low emissivity paint to mimimize supercooling below ambient temperature during the nighttime hours.

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 and slow control of the mirror temperature during the night. In addition, in order to track the nighttime temperature variations with higher fidelity, a coating heating capability is under development. 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 ambient temperature. Simulations and prototype testing show that the a 1 deg C temperature change can be achieved in about 15 min.

Active figure and alignment control

A pair of peripheral wavefront sensors (PWFS's), consisting of 8x8 Shack-Hartmann WFS coupled to CCD detectors, analyse the incoming wavefront, using reference stars in the field of view surrounding the science field, 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 while observing. The PWFS's patrol a 14 arcmin cassegrain guide field, providing virtually 100% sky coverage for this function.

Tip/tilt and fast focus correction

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

3. VERSATILE OPTICAL/IR CAPABILITIES

Broad wavelength coverage is a major feature of the Gemini telescopes. In order to achieve the throughput requirements and goals for the primary and secondary mirror the coating plants will need the capability for depositing a variety of mirror coatings. Gemini has undertaken devlopment programs for sputtered Alumimum coatings and for protected Ag coatings. The reflectivity of samples produced by these programs is shown in Table I.

Table I : 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

Both Mauna Kea and Cerro Pachon are very dry sites, except for the Southern Hemisphere summer months, with transmission in portions of the atmospheric windows around 2.3, 3.7 and 10μm in excess of 98%. In order to exploit the corresponding very low atmospheric background emission, the Gemini telescopes will have an IR configuration with telescope emissivity less than 4% and a goal of 2% in the thermal IR beyond 2.27μm. The IR configuration includes thin crosssection secondary vanes, a pupil stop at the secondary mirror, and minimum 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 Ag coatings together with APART analysis of the telescope configuration indicates that with Ag coatings on the primary and secondary mirrors, the Gemini telescope emissivity should approach the goal of 2%. (Dinger,1993)

In order to maintain the extremely low telescope emissivity for extended periods of time between mirror recoatings, an effective and frequent (about 1/week) in-situ mirror cleaning capability is required. Comparative cleaning tests using CO2 snow and Excimer lasers indicate potentially better cleaning performance for laser cleaning (Kimura, Kim, and Balick, 1994). Further cleaning tests on sample Aluminum and bare and protected Ag mirrors are underway.

The articulated secondary mirror will be capable of both two axis tilting for image motion compensation and "chopping" at 5 or 10 hz for 10 and 20μm observations. Both capabilities are incorporated into the tip/tilt mechanism supporting the secondary mirror.

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 configuration uses the fully deployed secondary baffle position, about 2 m diameter, to block direct sky illumination of a 12 arcmin field in the telescope focal plane. The IR configuration provides a fully retracted postion for the secondary baffle and an intermediate position with deployed diameter of between 1.1 and 1.2 m diameter.

The Cassegrain Instrument Support Structure (ISS) (Figure 5) incorporates acquisiton 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 telescope beam access to the uplooking instrument port. The ISS provides for three 2000 kgm science instruments mounted simultaneously, in addition to a Calibration Unit and an Adaptive Optics (AO) unit on opposite sidelooking ports. The AO module is accessed by a AO feed mirror in the ISS. The entire cassegrain assembly rotates to maintain the orientation of scientific instruments with respect to the sky during an observation (Montgomery, Robertson and Wieland, 1994).

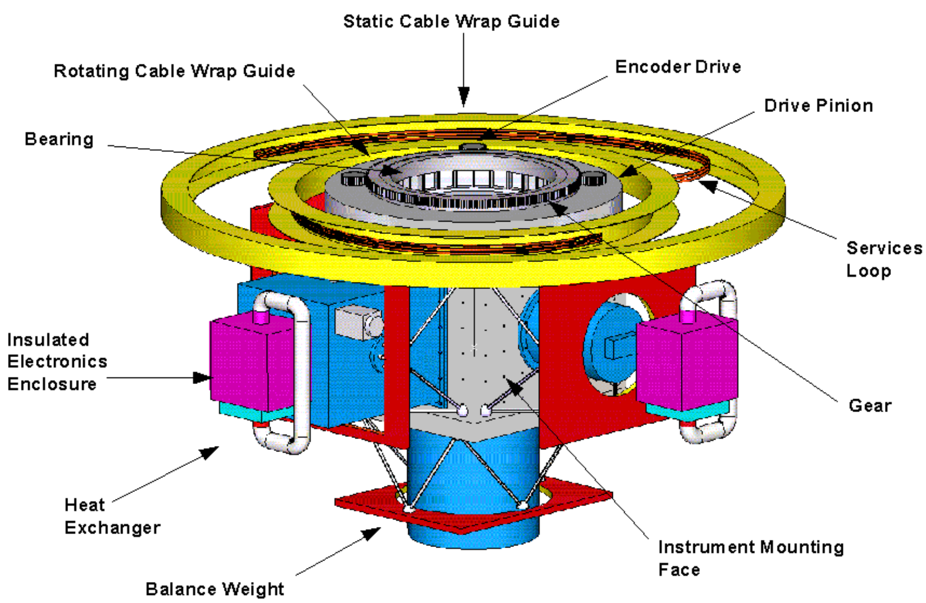


Fig. 5 The Instrument Support Structure(ISS) layout. Instruments can be mounted on the side-looking faces and on the up-looking face of the ISS.

4. EFFICIENT/ADAPTABLE OBSERVING

The observatory operating modes will be key to achieving maximum scientific productivity of the Gemini telescopes. Observing time will be at a premium on the Gemini telescopes, and every effort will be taken to obtain observations in a highly efficient manner that exploits the unique characteristics of the telescopes and sites. The facilities will support "classical" observing modes with the astronomer present at the telescope, but also a wide range of modes with the astronomer either participating remotely, or more innovative modes (for ground based telescopes) including queue scheduled observing where observatory staff carry out observations for the astronomer when the observing conditions are most apporpriate for those observations. At least 50% of the observing time will be allocated to queue scheduled observations in order to exploit the best conditions scientifically. In addition, to achieve maximum scientific productivity under changing sky conditions, the observer can readily change between mounted instruments during the night by reconfiguration of the control system and secondary baffle and redirecting the science beam with the science fold mirror. Efficient observation preparation tools, scheduling and rescheduling tools, environmental monitoring and data quality assessment capabilities will be provided. In addition, the necessary communications 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.

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

All of the effort going into the telescope and facility design naturally leads to tight performance specification for the facility instrumentation. Instruments can be mounted on three faces of the ISS. Table 2 lists the instruments that will make up the initial complement at each site (Simons, Robertson and Mountain, 1995).

A Natural Guide Star (NGS) Adaptive Optics system will be constructed for the Mauna Kea telescope, designed for use in the 0.9 to 2.5μm range and capable of delivering images with Strehl ratios of 0.5 at 1.6μm in median seeing conditions. The corrected beam can be fed to any instrument port on the ISS.

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.

Table 2: 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

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 1.8 um 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 use two 2kx4k CCD arrays, have resoltions of 50,000 and 120,000. The highest priority is throughput, particularly in the UV.

The commissioning instrument for the Cerro Pachon telescope will be a 1- 5µm imager borrowed from CTIO. This instrument is expected to be the Cryogenic Optical Bench (COB) currently in use on the KPNO telescopes.

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 spectrometer).

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.

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