Gemini Telescopes' Instrumentation Program

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ABSTRACT

The Gemini Telescopes are being built to exploit the unique infrared sites of Mauna Kea in Hawaii and Cerro Pachon in Chile. Both telescopes are being designed to deliver 0.1 arcsec images at the focal plane at 2.2 µm which will include all tracking and enclosure affects. Beyond 2 µm, using fast tip/tilt secondaries these 8 m telescopes will be essentially diffraction limited. In addition the use of protected silver coatings for both the primary and secondary mirrors and efficient in-situ mirror cleaning means the Mauna Kea telescope should be capable of delivering focal plane emissivities of ~2%. The baseline design for the Mauna Kea telescope also includes an adaptive optics system capable of feeding a 1-2 arcminute corrected field to near infrared instruments mounted at the *f*/16 Cassegrain focus. Fully exploiting the superb characteristics of the Gemini telescopes will require a new generation of instruments which will challenge both instrument designers and infrared array technologies. The baseline complement of infrared instruments includes a 1-5 µm imager, a 1-5 µm spectrometer, and a mid-infrared (8-25 µm) imager. Several optical instruments will also be built under the baseline instrumentation plan.

2. UNIQUE FACILITY DESIGN

The demanding performance specifications for the Gemini telescopes will be met through a design that incorporates a variety of technologies. Unlike most current observatories, in which many of the main observatory components are essentially distinct systems, in the Gemini observatories the entire assembly, from the external enclosure to the primary mirror cell down to the instruments will function as an integrated *system*, each component contributing to the quality of the focal plane at the science detector. In practical terms the Gemini observatories will be fundamentally limited by the physics of the atmosphere and intrinsic nature of the sites. Such an integrated approach to observatory design necessarily drives the instrument designs, if they are to effectively utilize the unique observing platform the telescopes offer.

2.1. Telescope Enclosure and Structure

Figure 1 shows an external view of the telescope enclosure currently under construction on Mauna Kea. Unlike many past observatories which include the support facilities (including computing, machine shop, storage, etc.) at the base of a cylinder with the observatory floor at the top, the Gemini observatories will have a telescope enclosure that is separated from the control building. This will minimize injecting unwanted heat into the dome interior, which can lead to degraded seeing. Perhaps the most distinctive aspects of the enclosure are the large wind gates located on each side of the dome. These structures are adjustable to control the amount of flushing the dome interior experiences. Under high wind conditions the gates will likely be closed in order to protect the telescope as well as minimize wind shake on the telescope structure. Overall the dome has minimal protrusions, yielding a clean aerodynamic profile that provides laminar flow into the enclosure under most ambient wind conditions. The dome surface will be painted with a special low emissivity paint to minimize absorption of solar radiation during the day. Under low wind conditions, high capacity internal air

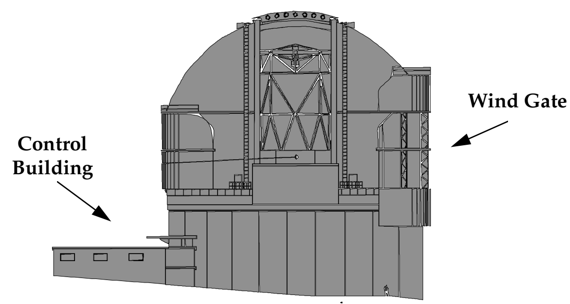


Figure 1 - The Gemini North enclosure is shown, as viewed from the east. It features a separate control building and large wind gates on the sides of the dome that will permit effective flushing of the interior.

handling units will draw exterior air into the dome. Finally, in order to minimize thermal equalization time after the dome is opened in the evening, during the day the interior will be air conditioned to a temperature level that is typically within ~1.5° C rms of the beginning of each night's observations (based upon a relatively simple predictive algorithm).

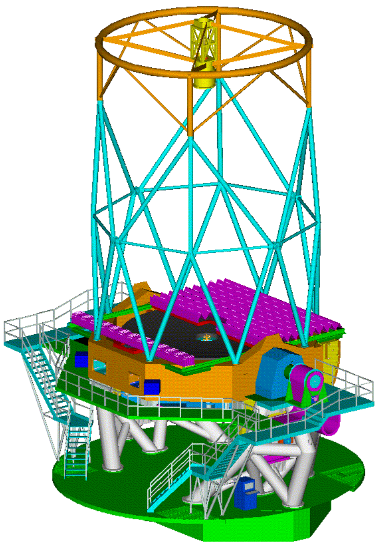


Figure 2 - The overall telescope structure is displayed. Of note is the exceptionally thin cross section of the truss system holding the secondary mirror in place, which helps minimize wind load and allows the structure to rapidly equilibrate with ambient temperature conditions.

Seen in Figure 2 is the complete telescope structure. The baseline design includes a removable top-end supporting an *f*/16 mirror capable of fast tip/tilt/focus adjustments. The structure suspending the secondary vanes has been light-weighted, which reduces its aerodynamic wind load characteristics and thermal response time to ambient conditions. The telescope elevation axis is located 20 m above the ground, which will place it above the ground seeing layer on Mauna Kea and Cerro Pachon. When combined with the fact that the primary mirror is located above the telescope elevation axis, it will be possible to effectively flush the air above the primary mirror under most wind conditions, thereby helping to reduce mirror/dome seeing.

2.2 Primary Mirror Temperature Control

The detrimental effects of temperature differences between a telescope's primary mirror and the air immediately above it have been well documented[1,2]. Measurements at CFHT demonstrate that it is crucial to keep the primary mirror temperature at or just below the ambient air temperature in order to minimize "mirror seeing". In Gemini several steps are being taken to minimize the impact of such temperature gradients. Shown in Figure 2 is a cross section of the primary mirror assembly, including the meniscus primary mirror. Gemini will use glycol cooled radiation panels just beneath the primary mirror to lower its temperature, as required by ambient conditions. While these panels have the capacity to cool the mirror fairly quickly, it will still not be possible to track rapid summit temperature changes with such a system. Accordingly Gemini is now investigating techniques for injecting electric current through the mirror coating, heating it slightly and acting in opposition to substrate cooling. Between these two mechanisms it should be possible to keep the primary mirror optical surface close (<0.5 °C) to the air temperature above it, thereby minimizing mirror seeing at this critical pupil. In the event of sudden changes in dewpoint (a fairly common occurrence on Mauna Kea), the mirror surface heating system can also protect the mirror from collecting dew, which is important if the low emissivity performance of the telescope is to be preserved, since condensed water on the coatings can lead to coating contamination and deterioration.

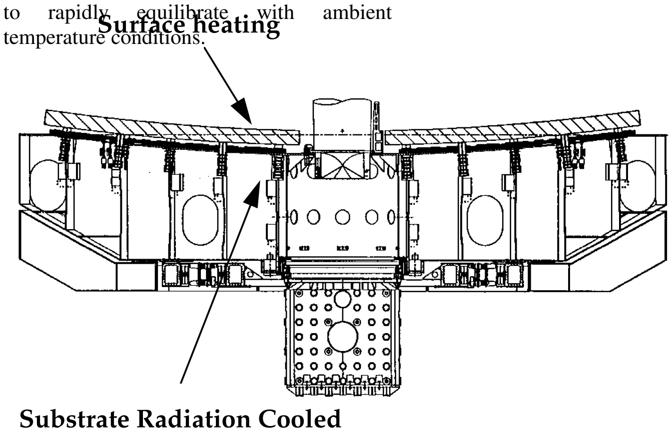


Figure 3 - A cross section through the Gemini primary mirror cell is shown. In order to minimize temperature differentials between the primary mirror and air above it in the beam, glycol pumped radiation panels mounted behind the mirror will cool it. Gemini is also investigating injecting current through the mirror coating to heat, with a fast time response, the surface coating of the mirror, effectively tracking ambient air temperatures at all times.

2.3 High Performance Coatings and Mirror Cleaning Program

In order for Gemini North to reach its specified emissivity of 4% (with 2% as the goal) rather "unconventional" mirror coatings must be used. Figure 4 shows the scientific importance of having a telescope with low intrinsic emissivity. Depicted is a model of infrared sky radiation for a typical Mauna Kea sky (1 mm precipitable water vapor). The flux is a complex combination of molecular line emission and thermal radiation. Of particular importance is the scientifically interesting 10 μm window. In this region the exceptionally low emissivity of the atmosphere makes the telescope's contribution significant, hence Gemini's 10 μm sensitivity is a strong function of the infrared performance of the mirror coatings.

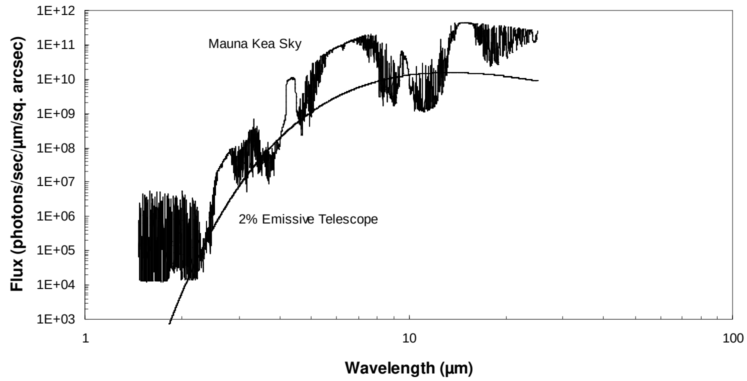


Figure 4 - A model of the infrared sky emission for a typical Mauna Kea night is shown. Strong OH line emission dominates at non-thermal wavelengths. Beyond ~3 μm a combination of molecular emission and thermal radiation determine the sky flux. Note that at ~10 μm where the emissivity of the sky is quite low, minimizing the telescope's contribution to the total background has a large impact on performance.

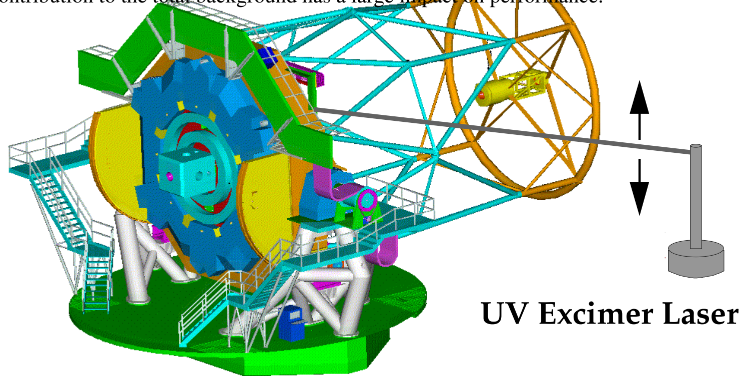


Figure 5 - The mirror cleaning system planned uses a UV excimer laser that raster scans a beam across the primary mirror surface with the telescope pointed toward the horizon. The secondary mirror should also be cleaned by reflected radiation during this scanning procedure.

To date essentially all telescopes have used aluminum as a coating material for a number of reasons, including its durability and the relative ease with which high quality coatings can be applied without using exceptionally low vacuum pressures. Unfortunately the intrinsic emissivity of aluminum is too high to permit reaching an effective telescope emissivity of only 4%, hence a silver based coating has been under development within the Gemini Project. Results to date indicate that it should be possible to achieve a total telescope emissivity slightly over 2% if the coatings developed under laboratory conditions can be replicated within Gemini's 8 m coating chamber. The coating will be deposited using state-of-the-art sputtering techniques in a stainless steel chamber (to achieve the reduced base pressures needed for silver deposition).

Maintaining such low emissivity implies a rigorous cleaning program. The baseline design for the Gemini telescopes includes the use of a UV excimer laser mounted on the observatory floor. With the telescope pointed near the horizon, a gimbal mounted mirror will raster scan a pulsed laser beam across the primary mirror, removing through several physical mechanisms dust and molecular contamination from the mirror. Nominally such a process is expected to require ~6 hours to complete and tests made on samples exposed to summit conditions indicate that such a cleaning exercise will be needed roughly once a week to maintain the Gemini emissivity specification. An additional benefit will be that the secondary mirror will intercept the once-reflected laser beam during the scanning procedure, cleaning it as well, though tests conducted at the IRTF suggest that such down-looking optics are not as susceptible to contamination as up-looking elements.

2.4 Facility Wavefront Sensing and Adaptive Optics

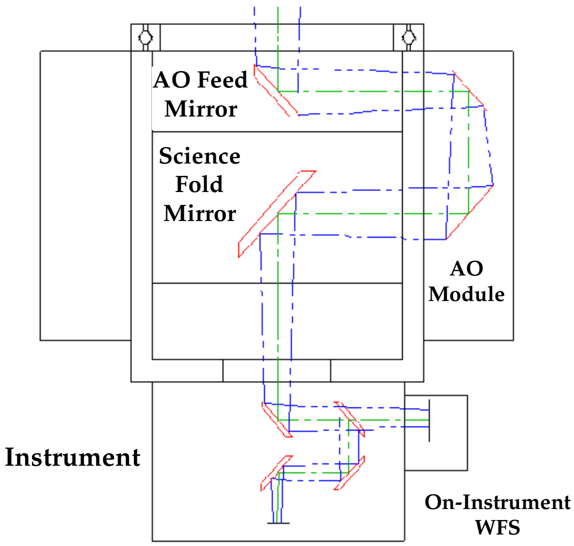


Figure 6 - The basic beam path of the central science field is illustrated. With the adaptive optics unit deployed, an AO feed mirror directs light into the AO module, where a deformable mirror compensates for atmospheric turbulence before sending the flux back into the A&G unit. From there a central science fold mirror directs the flux into an instrument mounted on the Cassegrain instrument support structure.

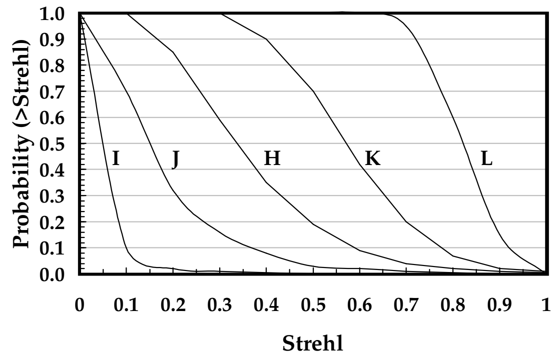


Figure 7 - Predicted mean strehls for the Gemini adaptive optics unit are shown for 5 band passes. These models assume median seeing conditions and the average field star density across the entire sky. Data for this chart was kindly provided by Rene Racine.

The Gemini telescopes depend upon wavefront sensing at several levels of temporal and spatial resolution in order to actively maintain optical performance under changing observing conditions. Mentioned above is the fact that the secondary mirror is articulated to compensate for tip/tilt/focus changes, both by atmospheric degradation of the wavefront and telescope wind shake. Furthermore the primary mirror's figure is precisely maintained by a combination of a hydraulic (passive) control system and 120 pneumatic actuators under the mirror, forcing its figure into a nearly optimal shape regardless of telescope attitude or wind load conditions. These active elements are controlled by wavefront sensors located in the acquisition and guidance (A&G) unit at the Cassegrain focus, which sense flux from field stars and translate wavefront errors into servo signals to drive active optical elements. There are two such "peripheral" sensors in the A&G unit. They work in combination with a sensor capable of high quality tip/tilt/focus measurements mounted on each instrument that senses flux from stars within the central 3 arcmin of the telescope's field of view. These on-instrument wavefront sensors also provide critical measurements of instrumental flexure that facility sensors mounted within the A&G unit could not detect. Working in combination with these sensors is a facility high order adaptive optics wavefront sensor located within the AO module (see Figure 6). The AO module will be a remotely deployable system capable of achieving on average fairly high strehls at near infrared wavelengths. The optical design of the AO system preserves the *f*/#, focal plane location, and pupil location so that instruments will not have to be reconfigured to function with the AO system. Figure 7 shows model predictions of the Gemini AO unit for 5 astronomical bands. This model incorporates the mean field star density of the sky and assumes median natural seeing conditions for Mauna Kea (r_0 = 23 cm at V). At H the Gemini AO system is expected to be able to deliver strehls of ~30% roughly half the time using only natural guide stars. One of the unique aspects of the AO design is that the deformable mirror will be conjugated to the mean turbulence layer above Mauna Kea, which has the effect of nearly doubling the diameter of the isoplanatic patch over what is possible by conjugating with respect to the primary mirror. The AO system is also being designed to permit a retro-fit of a laser guide star system early into the operations phase of Gemini North, which will have the effect of increasing sky coverage to nearly 100%.

2.5 Environmental Sensitivity and Queue Scheduling

To date most telescopes have had a relatively limited dynamic range in terms of delivered image quality. Even telescopes on such outstanding sites like Mauna Kea typically only experience a factor of ~2 in FWHM of images.

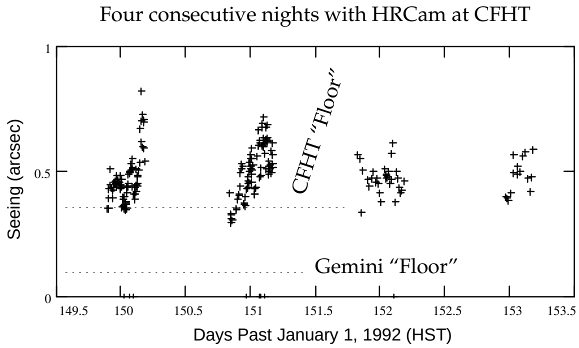


Figure 8 - A plot of 4 nights of image quality measurements at CFHT is shown to demonstrate the typical dynamic range of delivered image quality present at a telescope renown for high resolution imaging. Only a factor of ~2 is typical for CFHT. In Gemini's case, the dynamic range will be close to a factor of ~10 though, since image quality will not have a "floor" dominated by large static telescope aberrations or strong dome seeing.

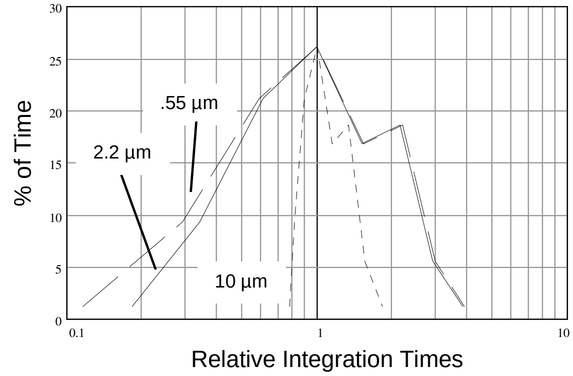


Figure 9 - Relative integration times for tip/tilt corrected imaging with Gemini are shown for three wavelengths. The natural seeing conditions assumed in the model were derived from Racine et al[1]. Large variations in exposure time will be required to achieve the same level of sensitivity with Gemini for non-thermal observations.

Such limited dynamic range is generally due to a combination of static aberrations in telescope optics and "dome seeing", or wavefront degradation due to a significant air temperature gradient between the air in the dome and outside the dome. Figure 8 shows the typical range in seeing present at one of the premier ground based sites in the world, CFHT. In the case of Gemini, delivered images will span nearly an order of magnitude in FWHM, due to active control of the optics and all of the aforementioned measures dedicated to reducing dome and mirror seeing. In terms of sensitivity, Figure 9 illustrates the range in exposure times required to achieve equivalent signal to noise ratios in an image of a point source. From this Figure it is clear that integration times can range by a factor of 5-10 at optical and near-infrared wavelengths, depending on (uncontrollable) natural seeing variations. For compact objects, where diffraction is important (i.e., beyond ~5 µm it totally dominates image quality) the range in integration times is much lower. Hence during periods of poor seeing use of the mid-infrared imager would still make efficient use of the telescope.

All of this leads to the need to flexibly schedule the Gemini telescopes so that science programs can be matched with varying observing conditions. In the baseline operations model for both telescopes, early into the operations phase at least 50% of science programs will be scheduled for observing time through a queue that is coordinated by Gemini operations. Staff astronomers will be responsible for conducting these queued observations and will have the task of matching on a nightly basis science programs (that are of course compatible with the instruments currently mounted on the telescope) with observing conditions. Such an operational model dictates streamlined instrument and telescope control with observing programs being substantially "pre-programmed" in computer controlled sequences of telescope and instrument configurations, thereby leading to a much more efficient and responsive observing environment than is typically found in observatories today.

3. GEMINI INSTRUMENTATION

The previous description of the Gemini telescopes gives the reader some insight in the unique design of these observatories. Modern design practices will lead to ground based astronomical facilities that offer *substantial* performance boosts over telescopes built recently, not just due to increased aperture but more importantly due to careful attention to factors that dictate image quality, throughput, and emissivity. The complete Gemini telescope *system* represents a multi-faceted effort toward delivering high performance, which includes the outer enclosure, telescope structure, careful control of the primary mirror temperature, extremely low emissivity mirror coatings, an aggressive mirror cleaning program, a variety of facility wavefront sensors working in concert with active optical elements, and queue scheduled observations. All of the effort going into the telescopes naturally leads to tight performance specifications for the facility instruments and the Cassegrain assembly used to support them, which the remainder of this report will be dedicated to describing.

Class	Mauna Kea	Cerro Pachon
Facility	Near-Infrared Imager Near-Infrared Spectrograph Multi-Object Spectrograph	Multi-Object Spectrograph High Resolution Optical Spectrograph Mid-Infrared Imager (shared N/S)
Shared	CFHT Fiber Feed to Opt. Spect. Michelle (shared with UKIRT)	Phoenix COB (commissioning camera)

Table 1 - A list of the initial instruments available at both Gemini sites is shown, which includes both the facility a currently planned shared instruments for each site. Note that Phoenix and COB will be shared with CTIO, and the facility mid-infrared imager will be shared between Gemini North and South.

Figure 10 depicts the Cassegrain cluster assembly, which includes the cable wrap, large rotating bearing and servo-drive system, and instrument support structure (ISS). The latter consists of a steel cube-shaped structure approximately 1.6 m on a side that rotates to compensate for field rotation of the alt-azimuth mounted telescope. Typically two of the five available ports will be occupied by a facility calibration unit and the adaptive optics unit. The remaining instruments can have masses up to 2 metric tons. Ballast weights will be used to tune the mass and moment of assemblies bolted to the faces of the ISS. Glycol fed through the cable wrap will be used to pull heat dissipated by ISS mounted electronics away from the Cassegrain area by mounting the electronics in special insulated enclosures with air-to-liquid heat exchangers. A central science fold mirror is used to direct light from the telescope into any of the side mounted instruments, or direct calibration or AO corrected focal planes (via the AO unit) into any of the instruments. A 7 arcmin partially vignetted focal plane can be delivered to any instrument with this system, as well as a higher quality 3 arcmin central unvignetted focal plane. The up-looking port will be used for optimal infrared performance since the central science fold mirror will be retracted to pass flux directly from the secondary mirror into up-looking instruments. This system permits rapid interchange between instruments, which will be required to operate the previously described queue-based observing plan, and consolidates calibration capabilities in a single unit. For instruments requiring extreme environmental stability (e.g., the High Resolution Optical Spectrograph) or that do not fit into the space or mass envelope of the instrument support structure, an off-telescope high stability facility will be provided within the telescope pier. Either a fiber or a direct feed (using transfer optics from the telescope) will be used to feed such instruments.

Table 1 lists the instruments that will be part of the initial complement at each site. Included are instruments that are currently planned to be shared between nearby observatories and Gemini North and South. Note that the facility mid-infrared imager is intended to be transportable between both sites. It should represent a powerful and completely unique capability for any of the telescopes in the South, including VLT. All of these instruments are described in detail in the following sections.

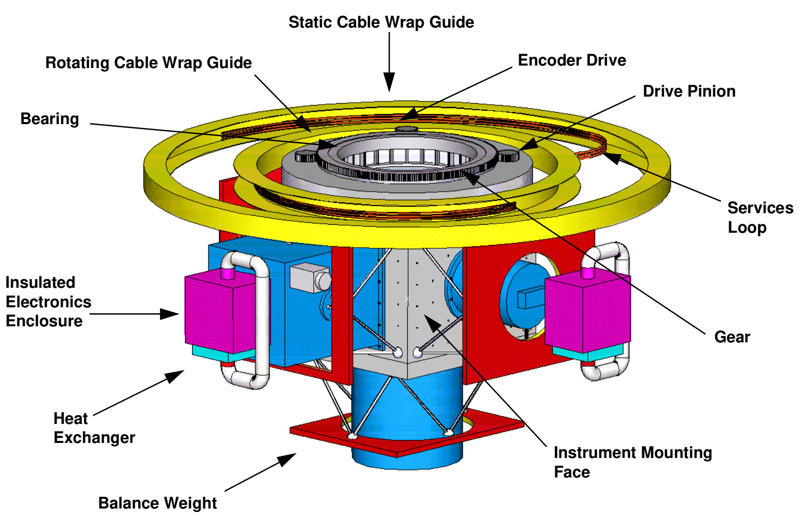


Figure 10 - An illustration of the planned Gemini Cassegrain instrument cluster is shown. A total of 5 instrument ports will be provided, though nominally one port would be used for a calibration unit and one for the adaptive optics module. An infrared optimized up-looking port is preserved. Electronics enclosures will use air-liquid heat exchangers to keep injection of heat into the telescope environment to a minimum.

3.1 Near-Infrared Imager

The University of Hawaii is currently designing the first of the Gemini instruments to be delivered to Mauna Kea, the facility near-infrared imager. This camera will serve the important role of being the commissioning instrument for Gemini North, hence will be used to verify the performance of key design areas including tip/tilt corrected imaging, total emissivity, and the adaptive optics module. The baseline design uses a single 1024^2 ALADDIN array as the detector, providing 1-5 μm wavelength coverage. A total of three plate scales will be available, including 0.12, 0.05, and 0.02 arcsec/pixel (or 123", 51", and 20.5" fields of view respectively). Approximately 20-30 filter slots will be available between a pair of filter wheels in the dewar housing. With a ~36 mm pupil size, filters that are ~50 mm in diameter can be used in the system. Additional wheels will house grisms and polarizing units (most likely a Wollaston prism) as well as several different pupil stops. A large carousel near the front of the mechanical layout will house a number of field stops and slits (for use with the grisms) as well as coronagraphic masks. The camera includes a pupil viewing mode that will image the secondary mirror across ~70% of the array's width, providing adequate resolution to identify potential hot-spots in the secondary mirror or surrounding support structure. The optics are made of ZnSe, ZnS, BaF_2, and LiF (a total of 7 lenses for each plate scale) and are all spherical in design except for the high index lenses in the fast (*f*/6) camera, which will use aspheres on a single lens surface. Though several plate scales are available, the lenses used for each will remain stationary and a set of simple flip mirrors will be used to direct flux through one of the three camera sets. The design uses the same field lens and collimator pair for each plate scale, only the camera lens sets change. The optics will be oversized to accommodate the future arrays as large as ~2000x2000 pixels so that retro-fits of next-generation infrared arrays is simplified.

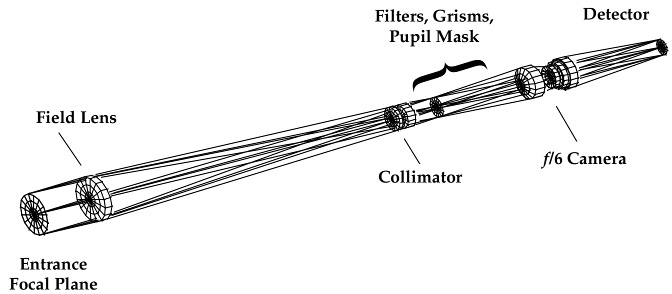


Figure 11 - The basic optical design of the near-infrared imager is shown. The imager will have three plate scales, all of which will share the same field lens and collimator but use different reimaging cameras. An ALADDIN 1024^2 InSb array will be used for the detector. The design was kindly provided by Joe Hora and Klaus Hodapp for this paper.

Design drivers in the imager stemming from Gemini's performance specifications include keeping the instrument's total emissivity (including ghosting, scattering, internal radiation leaks, etc.) to <1%. This specification will likely require the use of foreoptics to effectively "seal" the reimaging section of the imager from stray radiation. Furthermore a high resolution imaging mode that is matched to the PSF produced by the AO unit is required, as well as a pupil viewing mode to optimally align the imager to reduce background flux.

3.2 Near-Infrared Spectrograph

NOAO is currently completing the design of Gemini's near infrared spectrometer, which will be delivered to Mauna Kea for commissioning. Like the near-infrared imager, the spectrometer will incorporate an ALADDIN array as its main science sensor. The current design uses an engineering grade ALADDIN array as a post slit viewer. Acquisition would therefore typically be conducted by first acquiring the target with the infrared viewer in the spectrometer, then executing a precision offset to place the target on pixels known to contain the slit when rotated into the beam. Two resolutions are planned initially, including R ~ 2000 and 8000, the latter being high enough to resolve OH emission lines in the sky for effective removal during data processing. A single plate scale of 0.05 arcsec/pixel is in the baseline design but the Project and NOAO are seriously considering including a coarse plate scale of 0.15 arcsec/pixel to better adapt the system for nights that do not have exceptional seeing. The slit length with the 0.05 arcsec/pixel mode is ~50". Future upgrades are being considered as part of the design to make sure that enough room is reserved to permit straightforward retro-fits. These upgrades include an integral field mode, which most likely will consist of an array of microlenses which feed into a fiber system that passes the decomposed entrance focal plane into the slit, creating a linear array of spectra that can be reconstructed into a data cube containing both spatial and spectral information. A crossed dispersed mode and higher resolution modes (R ~ 15000 - 30000) are also being considered as future upgrade paths within the instrument.

Of particular importance in the design of the spectrograph is baffling, stray light, and emission from inside the dewar. The instrument's contribution to the total emissivity budget is 1% (recall the telescope should have an emissivity of ~2%). When coupled to the Gemini AO unit slit widths of only 0.10" will be used, which significantly reduce unwanted sky flux and boost sensitivity for point sources. Under such conditions the brightness of the sky between the OH lines will be <0.1 e-/sec at the detector. Such ultra-low sky backgrounds and narrow slits imply "new thinking" in infrared instrument design, with careful attention being paid to scattering within the system through the use of efficient foreoptics, proper "disposal" of diffracted radiation at the slit, and mechanical flexure in order to maintain high throughput over extended integrations with very narrow slits.

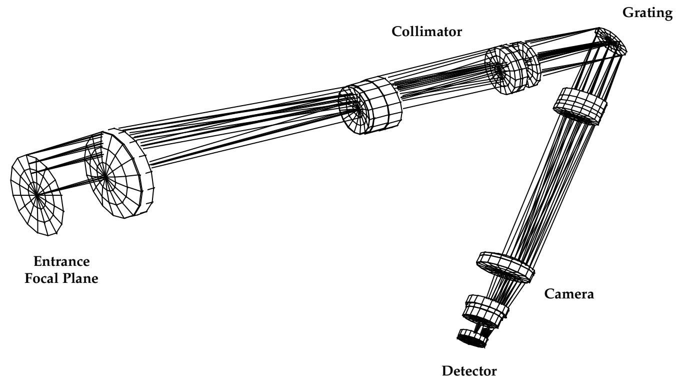


Figure 12 - The optical layout of the multi-object spectrograph is shown. A single fold at the grating is used to reduce the overall size of the instrument. A 4kx4k CCD will be located at the MOS focal plane. Not shown is an ADC that is mounted in the ISS wall to support this instrument. The optical design was kindly provided by Chris Morbey at DAO.

3.3 Mid-Infrared Imager

The low emissivity and high strehl thermal infrared imaging capabilities of the Gemini telescopes will lead to very effective use of mid-infrared instruments. Accordingly, Gemini plans to begin procurement of a mid-infrared imager in 1995 within the U.S., with eventual delivery late into the commissioning phase of Gemini North. The imager is intended to be a relatively simple camera dedicated to high performance imaging. The highest design priority for the instrument is broad-band 10 µm imaging. As demonstrated in Figure 9, such an imager, when combined with Gemini's fast tip/tilt compensating secondary mirror, should yield nearly diffraction limited 10 µm images under most Mauna Kea natural seeing conditions. The same will be true for Cerro Pachon. The imager must therefore be able to exploit the high background characteristics of state-of-the-art mid-infrared arrays. It is expected that a Si:As IBC array with a format approximating ~256x256 will be incorporated into the imager, offering coverage from ~5 to 25 µm. A single plate scale of ~0.13 arcsec/pixel will be used to critically sample a diffraction limited 10 µm point source PSF. Furthermore, high throughput is a premium in the instrument design, in order to fully take advantage of the coatings used in the telescope optics. Like all of the infrared instruments, the imager's contribution to the total system emissivity must be kept as low as possible to exploit the ~2% telescope emissivity, and the instrument specification will likely be <1% effective emissivity (including ghosting, scattering, radiation leaks, etc.). A filter capacity of ~20-30 filters will be needed to supply users with an adequate complement of broad and narrow band filters.

Unlike the other infrared instruments, the mid-infrared imager will not have an on-board wavefront sensor due to the lack of dichroic availability that can effectively pass visible radiation and reflect infrared radiation across such a broad thermal band. Luckily, running the imager without an on-board sensor should not significantly degrade its performance since the A&G unit's peripheral sensors should be able to provide adequate tip/tilt correction, i.e., the size of the isoplanatic patch is large enough at 10 µm that an off-axis wavefront sensor can be used for atmospheric compensation.

3.4 Multi-Object Spectrographs

Both Gemini North and South will have a multi-object visible light spectrograph delivered during commissioning. Design and fabrication of the Gemini MOS is a collaborative effort between Canada and the United Kingdom. The design chosen is based upon precisely fabricating and locating a plate containing many small slits within the spectrograph's entrance aperture. The basic viability of this design and spectacular multiplexing power of these instruments has been demonstrated at the CFHT with MOS/SIS[3]. With a ~5.5 arcmin field of view the Gemini MOS should be able to locate well over a hundred slits in a single mask. Actual mask production will be completed with a laser milling machine located on-site. Observers will therefore use the MOS imaging mode to record an image of the sky and select the sizes and locations of slits to cut in the mask before milling the mask, installing it in MOS, and recording a spectrum through each slit. It is worth noting that the MOS imaging mode is the only science grade visible light imaging mode available in the first generation of instruments.

Figure 12 shows the optical layout of MOS. A grating is located at the single fold in the optical path. A pair of 2048x4096 CCD's with 15 µm pixels will be used as the detector, providing 0.08" pixels. The wavelength range of the optical design extends from 0.37 to 1.10 µm. There is a scientific interest in optimizing the MOS at Gemini North for the near infrared, perhaps out to ~1.8 µm, so that spectra can be recorded at J and H when a detector is provided, while the science interest for Gemini South is for MOS to have good UV throughput, which is well tuned for the aluminum coatings planned for that telescope. The forward slit environment of MOS is fairly complex, since it houses a large number of masks in a "jukebox" changer, an on-board wavefront sensor, an integral field unit, and an atmospheric dispersion compensator. Slits as narrow as 0.25" should be possible when this instrument is used in combination with the AO system. Spectral resolution up to $\sim 10^4$ is planned. Figure 13 shows the preliminary mechanical layout of the main optical components in MOS. A central truss system will be used to suspend the optical elements as well as the CCD dewar from the ISS. A grating turret with micropositioners behind each grating will be used to switch between gratings remotely. Finally a filter wheel that is mounted on a separate structure and measuring ~1 m in diameter will be used to house a large number of filters for various imaging and spectrum order sorting functions. Not shown is the forward slit environment.

One of the more interesting features of MOS will be its integral field mode. This mode is based upon using a lenslet array (containing $\sim 10^3$ elements) in the pre-slit environment to slice the focal plane into a multitude of small components. Each lenslet is fiber coupled with the output sent to a linear array of fibers terminating at the nominal location of the slit. From there it is possible to reconstruct an image at a particular wavelength, or extract a spectrum from any point in the field of view. This mode is well adapted to the AO unit since it makes optimal use of the AO corrected field, unlike a slit which of course blocks much of the corrected field. The sky will be sampled with several "out board" fibers located ~1 arcmin away from the integral field unit's 8 arcsec field of view.

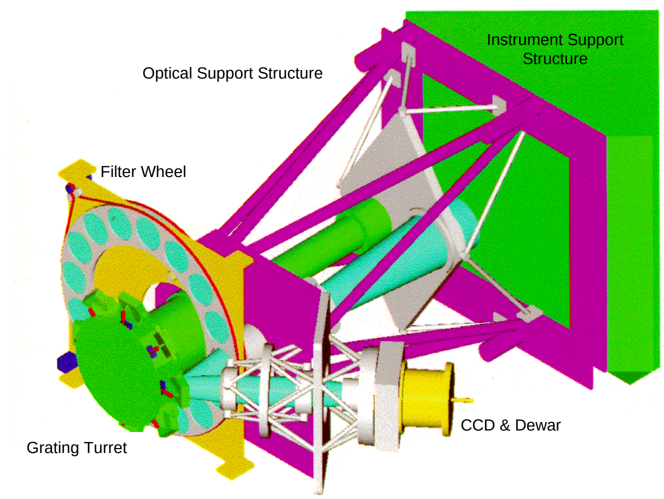


Figure 13 - The preliminary mechanical layout of key components in MOS is shown. A truss system is used to support the lens system and a CCD/dewar within the instrument. A set of gratings located on a turret folds the beam. A separate mechanism is used to hold filters. Not shown in detail is the slit environment. This design concept was provided by DAO for this paper.

3.5 High Resolution Optical Spectrograph

The United Kingdom is currently working on the design for HROS, which will be delivered late in the commissioning phase of Gemini South. Preliminary designs include the use of a pair of 2048x4096 CCD's with 15 µm pixels as the HROS detector. High throughput is a top priority in the design, particularly in the UV where, like MOS-South, HROS will be tuned to take advantage of the high performance aluminum coating applied to telescope's mirrors. Throughput requirements include the system having at least 10% total throughput at R = 50000 (500 nm), with 15% as the goal. Spectral resolution will initially be in the range of 30000 to 80000, with a higher resolution mode of ~120000 as a future target (note that 0.6" slits will yield R = 50000). Slits will extend up to 1 arcmin in length. Though HROS is Cassegrain mounted it has a very tight flexure specification of 2 µm per hour of tracking, or 5% of a resolution element in a 1 hour exposure. For higher resolution applications HROS can be mounted in the high stability lab (in the telescope pier), where a specification of 30 m/s spectral resolution has been set. The need for a slit viewer is under review at the time of this report, since much of the foreseen acquisition requirements of the instrument can likely be fulfilled with the acquisition camera in the A&G unit. An image slicer will likely be used as well, making the need for an on-board wavefront sensor unclear at this early stage in the instrument's design.

3.6 Shared Instrumentation

Sharing instrumentation with other nearby observatories will significantly expand the science capabilities of the telescopes. At Gemini North, two instruments are under serious consideration for use with Gemini. First, ROE's Michelle, which is a mid-infrared imager/spectrometer, will be shared between UKIRT and Gemini. Michelle is based upon a Si:As IBC array with a format of ~256x256 pixels. It will therefore support work from ~8-25 µm. When configured as a long slit spectrometer, a plate scale of 0.18 arcsec/pixel will be used with 3 resolutions. At R~200 the entire 8-13 µm window can be recorded in a single exposure, while at R ~ 1000 sensitivity to narrow emission lines is maximized. In a high resolution (R~30000) mode Michelle should support velocity resolved observations of narrow emission lines. When configured in an imaging mode Michelle will use a 0.10 arcsec/pixel plate scale to critically sample the diffraction limited mid-infrared Gemini PSF. Michelle should provide background limited performance in all of these modes. Since it has an imaging mode less pressure will be placed on the Gemini facility mid-infrared imager to be located at Mauna Kea, though Michelle may not be as fully optimized for broad-band deep imaging as the facility imager.

Gemini is currently considering routing a fiber between the Mauna Kea site and CFHT so that Gemini users will have access to a high resolution optical spectrometer via CFHT. The Coude *f*/4 optical spectrometer at CFHT, or GECKO, uses an echelle grating to provide dispersions of ~ 1 Å/mm from ~0.4 to 1.0 µm using various grating orders. In principle the fiber would extend from the Cassegrain environment at Gemini to the entrance slit at GECKO, spanning ~400-500 m in total length. Users located at Gemini would remotely control the spectrograph, with control signals and data being passed across the existing Mauna Kea summit fiber network.

CTIO is currently planning to share 2 instruments with Gemini South, including COB (Cryogenic Optical Bench) and Phoenix. The latter is a high resolution near-infrared spectrograph that will use part (512x1024) of an ALADDIN array as its main science detector. High resolution 1-5 µm echelle spectroscopy will be offered at a resolution of R~100000 (2 pixel wide slit) using an 0.09 arcsec/pixel plate scale. The slit length will measure 14 arcsec and the delivered spectral format will be a single order on the array at any one time, for a band pass of ~1500 km/sec.

COB will act as the commissioning instrument for the Cerro Pachon telescope. Though it currently houses a 256^2 InSb array, NOAO plans to upgrade it to a 1024^2 ALADDIN array. A plate scale of 0.05 arcsec/pixel will be used to critically sample the Gemini tip/tilt corrected near-infrared PSF. Two filter wheels with a total of 40 filter positions are available for both broad and narrow band applications. COB offers a low resolution (R ~ 500) grism

Figure 14 - Summary charts for the spectral and spatial coverage provided with the initial compliment of instruments at both Gemini sites are shown. A considerable amount of parameter space is being covered at Gemini North with this instrument line-up, while Gemini South is initially emphasizing optical/UV science in the instrumentation plan.

spectroscopy mode in the J, H, and K bands as well as polarimetry.

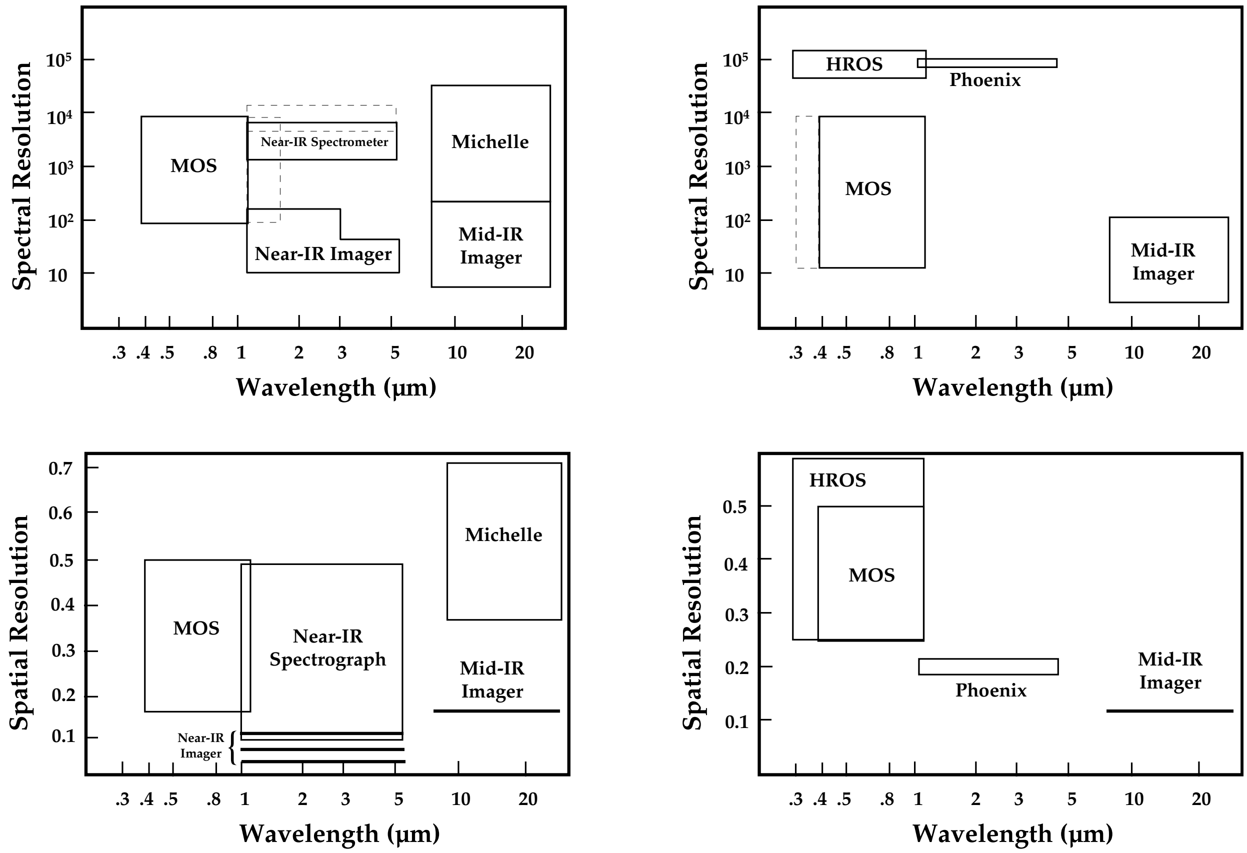
Phoenix and COB will incorporate visible light wavefront sensors to make them fully compatible with the Gemini active optic control system (i.e., to provide control for the active secondary), in much the same way that facility instruments will have such sensors. A direct imaging and pupil imaging mode will be available in both as well. Like all of the Gemini infrared instruments, closed cycle cooling will be the adopted standard for COB and Phoenix.

3.7 Summary of Instrument Capabilities

Figure 14 depicts the spatial and spectral parameter space covered by the initial instrument complement at both Gemini telescope sites. Such broad capabilities at the beginning of formal operations for each telescope will permit fairly rapid scientific "return" for the considerable investment being made in the telescopes. The northern site will have broader capabilities in the infrared, but over the lifetime of Gemini it is certainly possible that different coatings will be applied at each site to enhance the performance (UV vs. infrared) for various scientific applications.

Mauna Kea **Cerro Pachon**

Furthermore Gemini will have on an on-going instrument development program as it enters its operations phase that



will serve to enhance and upgrade “phase 1” instruments and procure next-generation instruments as well.

4. REFERENCES

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