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Progress Report: *Gemini's Instrument Development*

Gemini's instrument program is firing on all cylinders and has already realized many milestones in 2012, ranging from new detectors for the Gemini Multi-Object Spectrograph, which are significantly extending Gemini North's red sensitivity, to remarkable progress on the revolutionary GeMS multi-conjugate adaptive optics system at Gemini South. Download this article and also learn about progress on repairs to FLAMINGOS-2 and the integration of the Gemini Planet Imager, which will help define Gemini's future capabilities.

The last six months at Gemini have been rich in instrument development activities. This article focuses mainly on the Development Team's three top priorities in 2011B: (1) the new E2V Deep Depletion CCDs for the Gemini Multi-Object Spectrograph at Gemini North (GMOS-N); (2) FLAMINGOS-2 at Gemini South, and; (3) the Gemini Multi-Conjugate Adaptive Optics System (GeMS) at Gemini South. We will also summarize other activities such as the Gemini Planet Imager (GPI), Gemini's Remote Access Spectrograph (GRACES), the Gemini High-resolution Optical Spectrograph (GHOS), and the long-range planning process now underway for instrumentation.

New GMOS-N CCDs

In early 2011, we experienced difficulty in getting the Hamamatsu CCD and controller system to perform up to its potential. In light of this, we decided to take an intermediate step and purchase/retrofit new E2V Deep-Depletion CCDs into GMOS-N. The Development Team accomplished this upgrade during an instrument shutdown in October and November 2011. The new hardware was recommissioned and ready for science use by December 2011.

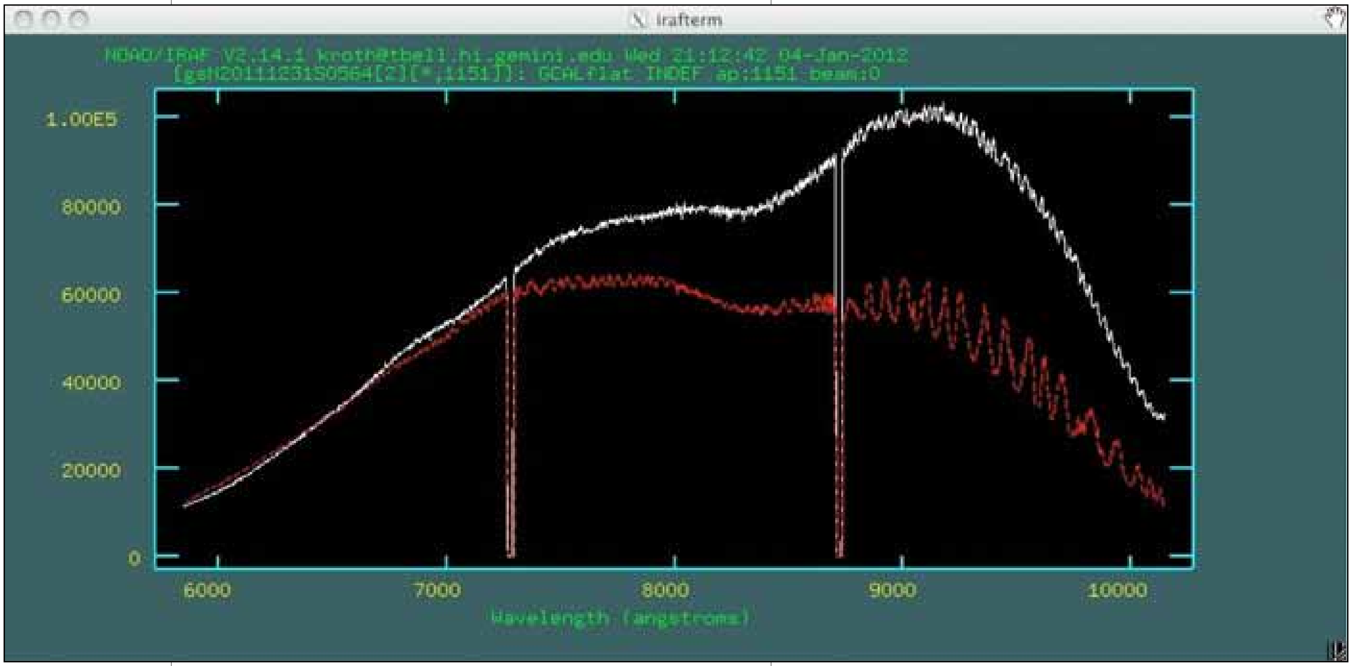


Figure 1.
GCAL spectral flat data of new E2V Deep Depletion CCDs (white curve) versus the old CCDs (red curve) from GMOS at Gemini North. The data were taken before the detector gain values had been precisely measured and roughly scaled to have the counts match at 650 nm. The data also could not be used to derive any absolute response, due to inherent small variability in the GCAL quartz halogen bulb brightness. Notice, however, the higher QE and the near absence of fringing with the new detectors.

The gain in depth in z-band images is about 0.5 magnitude due to the increased quantum efficiency (QE) and larger bandpass toward the red. Compared to the old CCDs, the new ones also have an increased sensitivity at the blue end of the spectrum with 25 percent more QE at 400 nanometers (nm), compared to 75 percent at 900 nm (see Figure 1). The improved blue QE comes close to matching that currently obtained with GMOS at Gemini South.

We also have on-sky imaging photometric zero-points for all of the broad-band filters, showing that the realized on-sky gain in sensitivity is almost 0.4 magnitude in g-band. In addition, we now have two new filters (Z and Y) installed and available in GMOS at Gemini North. Given the increased blue sensitivity, we are currently exploring the option of replacing the u-band filter that delaminated back in 2004.

The Hertzberg Institute of Astrophysics (HIA) delivered the Hamamatsu CCD system to Gemini in December 2011, and we are now working in the lab to decrease the obtained readout noise from the system. Our initial explorations revealed signal quality and line filtering as crucial keys for noise reduction. We have also sought advice from various experts from within the Gemini community and have reached a consensus on how to pursue these issues.

Preliminary tests along these lines are very encouraging, so we will continue implementing these improvements in the next few months. We hope to begin installation of these CCDs into GMOS-N starting January 2013. GMOS-S should be upgraded by the second quarter of 2013. To find the latest news and updates about the detectors, go to: www.gemini.edu/sciops/instruments/gmos/imaging/?q=node/10424

The Latest on FLAMINGOS-2

In 2011, the Development Team finished a cycle of improvements to FLAMINGOS-2 in La Serena and installed the instrument back on the telescope on November 25th. After completing a successful technical commissioning on the sky (including the first multi-object spectra, see Figure 2 on next page), we intended to start System Verification with a Call for Proposals in March 2012.

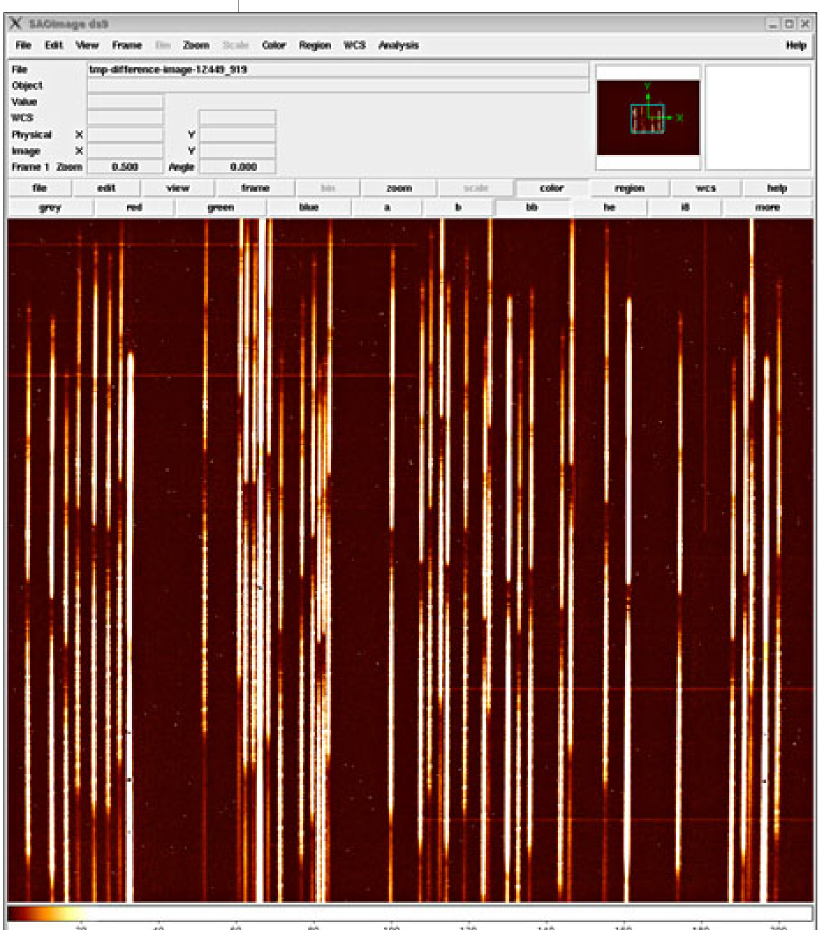
But FLAMINGOS-2 work came to a sudden halt at the end of January 2012, when we discovered some vignetting in the images. After a warm-up and inspection inside the instrument, we realized the main field lens (first lens of the collimator and part of the Multi-Object Spectrograph's dewar) was fractured.

To both determine the root cause and initiate mitigation paths (new lens procurement, *etc.*) the team immediately began an escalation activity. We have also gathered a committee of external reviewers from the community to advise us on our analysis and confirm the best steps forward. Additionally, our colleagues at the University of Florida have joined us to help the situation.

Unfortunately, despite a lot of brainstorming and analysis, it has proved very difficult to identify one single root cause. Instead, we have identified several possible causes that we are addressing with mitigation strategies. During the escalation, we applied a few standard tools and methodologies.

For example, to design the new repair and understand the new schedule, we performed a careful Kepner-Tregoe analysis of the possible causes, and a PERT analysis of the critical path (three-point estimates to find out the optimistic and pessimistic, expected and optimistic, end dates).

Figure 2.
Example of MOS spectra observed with FLAMINGOS-2 in January 2012.



As of the end of May 2012, we are conducting thermal experimentation (temperature sensors were epoxied on the broken, but rebonded, lens) and thermal modeling to measure the thermal stress in the glass. This will increase our confidence level in the new design with real *in-situ* data.

In general, we have decided to build in as much safety margin as possible: making several improvements like polishing the edges of the new lens to relieve stress in the glass, modifying the cell mounting arrangement, and propagating some of these changes to other lenses in the collimator and camera. We currently plan to have the instrument back on the telescope at the end of 2012 and recommissioned by March 2013 (this is our expected date; the pessimistic scenario adds another 12-week contingency).

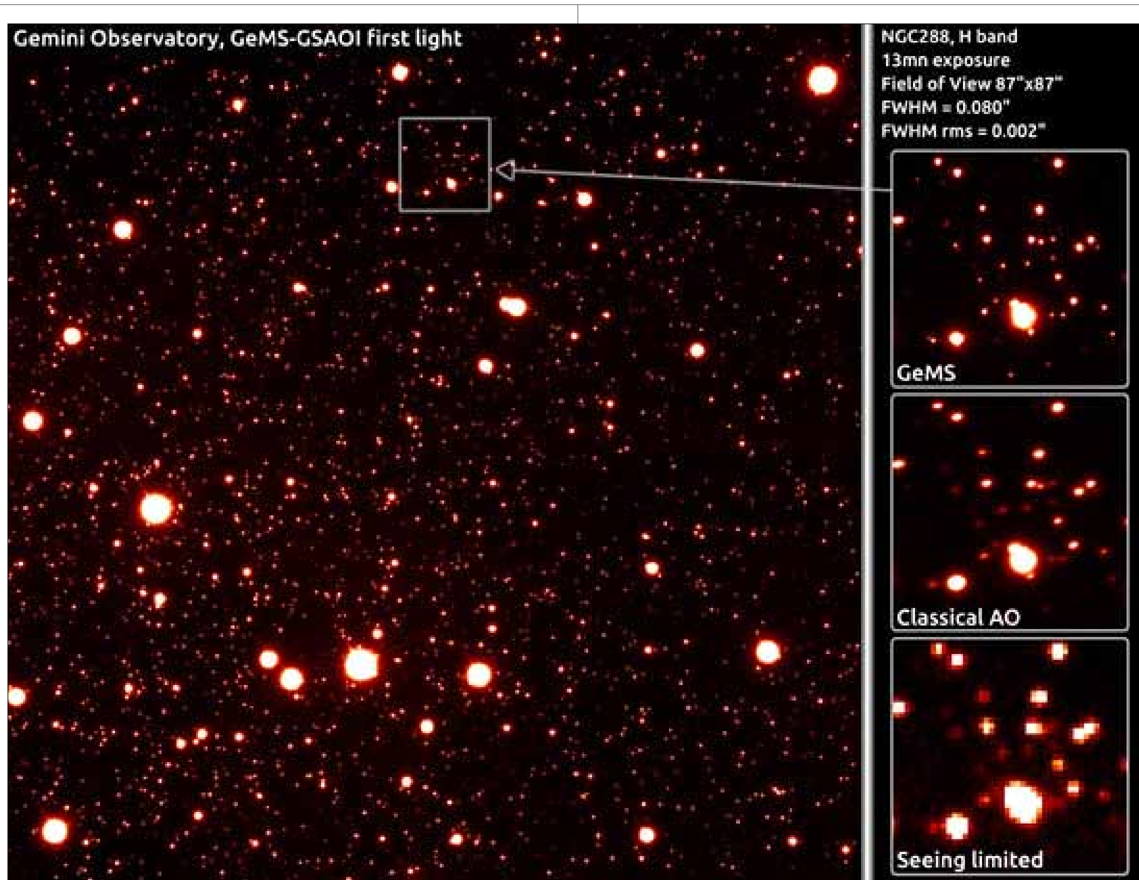
GeMS Commissioning Progress

During the last six months, the Gemini Multi-Conjugate Adaptive Optics System (GeMS) team at Gemini South achieved several milestones with GeMS commissioning.

The results shown in Figure 3 (next page) summarize most of these achievements. This is one of the first images acquired with the Gemini South Adaptive Optics Imager (GSAOI — a large field-of-view, near-infrared camera); it targets a portion of the globular cluster NGC 288. The field-of-view is 87 x 87 arcseconds, which is about 16 times larger than any other current adaptive optics (AO) system.

This image truly illustrates the gain brought by Multi-Conjugate AO (MCAO), namely a uniform image quality across a large field-of-view. Static residual aberrations still limited performance, but the Strehl ratios (SR) measured in this image are around 15 percent (H-

Figure 3.
Gemini South's first light image from GeMS/GSAOI shows extreme detail in the central part of the globular star cluster NGC 288. North is up, East is right.



band), with a variation of only a few percent across the whole field.

Since then, better performance levels have been reached. We can achieve typical SR of 35 percent in H-band (full-width at half-maximum (FWHM) = 50 milliarcsecond. Figure 3 represents the first compensated image with GeMS and is truly the result of a large effort by the GeMS and GSAOI teams.

After last year's engineering winter shutdown, GeMS came back on-sky in November 2011, as originally planned. It was an almost brand-new GeMS, counting photons with a better performing, and especially more stable, set of subsystems. Commissioning resumed at a rate of one week per month around the time of full Moon. Since we obtained the first compensated images, the level of excitement has been maintained at an extremely high level.

The next runs, in January and February 2012, were dedicated to the commissioning of the remaining functionalities, as well as the integration of GeMS and GSAOI within the observatory's high-level software and telescope control. Excellent progress has been made in these areas and many others.

For instance, the Observing Tool (OT) has been redesigned so it now includes an option to select the best asterisms to be used with GeMS. It also provides users with an estimation of the performance over the field. Check for the latest version of the OT at www.gemini.edu/sciops/observing-with-gemini?q=node/11161.

During the March run, and due to an issue with the cooling of GSAOI, we tried to use GeMS in conjunction with GMOS instead. Although this combination is not intended to be offered as a standard mode in the immediate future, the configuration was useful for commissioning/verification purposes, and it demonstrated the capabilities of GeMS over a broad spectral range.

To some extent, the GeMS/GMOS performance for this wavelength hints that the gain

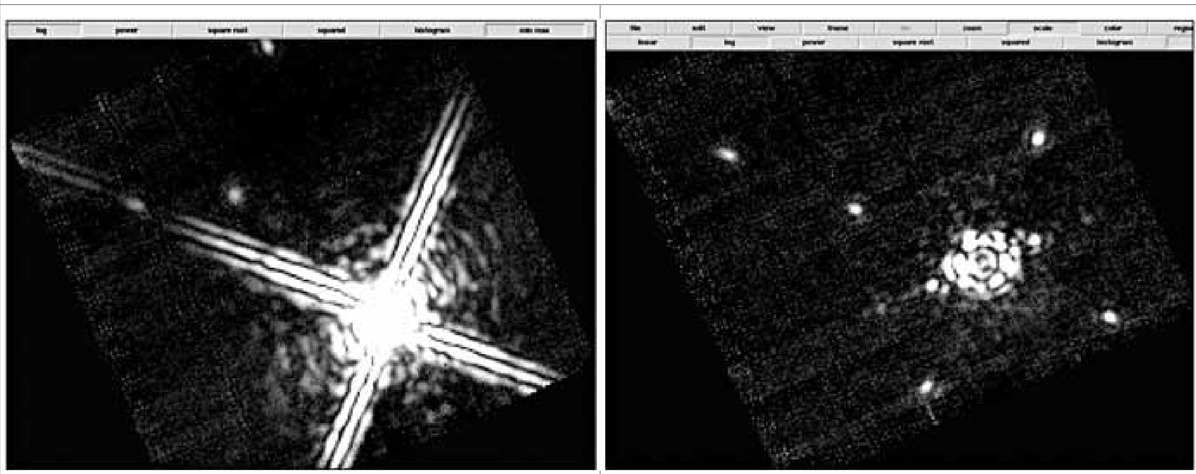


Figure 4.
GPI PSF images using a telescope simulator. The exposure time for each image is 2 seconds. Left: Image without the coronographic mask. Right: The same configuration but with the coronographic mask in the beam. The exposure time in both images is identical and shows the efficiency of the coronographic mask to diminish the light from the core.

brought by MCAO is close to one of a ground-layer AO system: a gain by a factor of 2 to 4 in the FWHM over the natural seeing conditions.

During the April 2012 commissioning run, we offered the user community their first opportunity to use GeMS with GSAOI. Given the unique scientific potential of GeMS and the current interest in this capability, we also invited astronomers to submit scientifically appealing targets that may be observed during the engineering runs. The intent is to provide a suite of scientifically useful data that demonstrates the unique capabilities of GeMS with GSAOI. We hope these provide a catalyst for subsequent observing programs. Unfortunately both runs were mostly weathered out and no data were obtained.

The next opportunity for these observations is is anticipated during the full end-to-end GeMS testing of System Verification (SV) with GSAOI that will be conducted in late 2012. System Verification will occur after a second engineering winter shutdown (from May to September 2012) which is intended to consolidate and ultimately solve any remaining issues.

Last, but not least, the GeMS and GSAOI websites have recently been refurbished. You'll find more information on commissioning and results (respectively) at: www.gemini.edu/instruments/gems and www.gemini.edu/instruments/gsaoi

Gemini Planet Imager (GPI): Project Update

During the first half of 2012, excitement ran high among all of those working on the Integration and Test (I&T) phase of the Gemini Planet Imager (GPI) at the University California Santa Cruz (UCSC). A tremendous amount of effort put forth by many individuals and groups — including the instrument builders, the extended GPI community, and the Gemini project team — resulted in a bounty of delightful end-to-end results.

To summarize, GPI, a next-generation exoplanet-finding instrument, is comprised of four major hardware subsystems: opto-mechanical super-structure (OMSS), adaptive optics (AO) system, interferometer calibration system (CAL), and Integral-Field Spectrograph (IFS). Prior to December 2011, all had been integrated except for the IFS. On December, 15, 2011, the University of California Los Angeles transported the IFS to UCSC. During the following month we achieved our first major milestone of 2012: the OMSS integration of the IFS into GPI. After pumping and cooling down the IFS, we obtained the first pupil images and spectra in late January and early February, respectively.

With the instrument fully assembled, the System Characterization tasks began on March 1st. During this process we discovered a number of issues that led to the formation of a remediation work package. We scheduled and

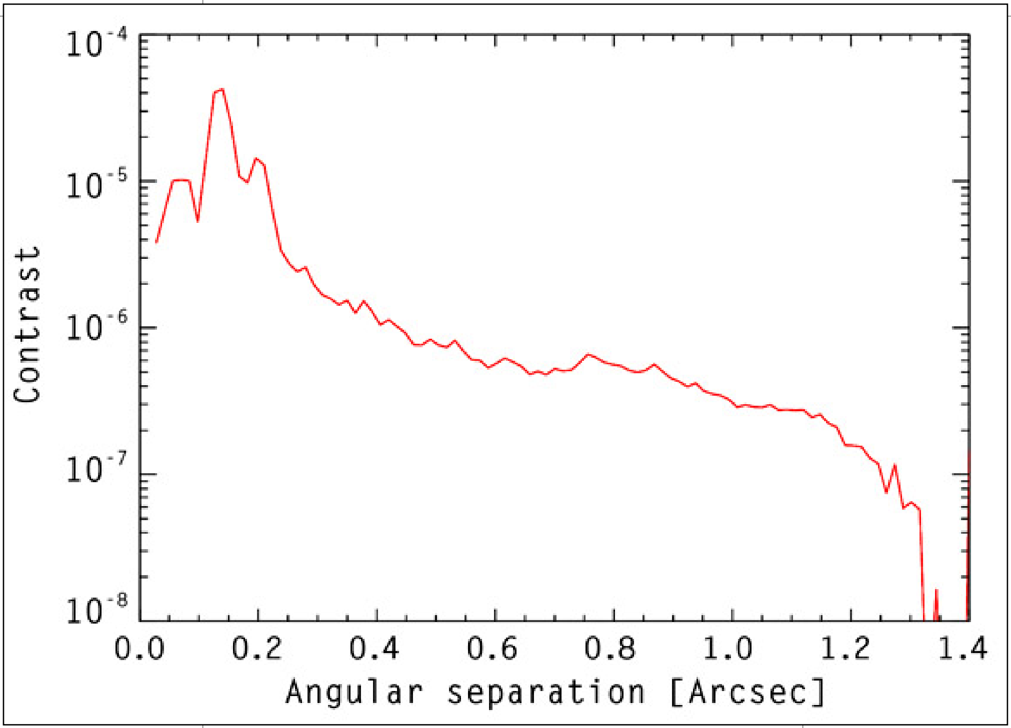


Figure 5.
Contrast vs. radius measured from the two images in Figure 3. The noise floor is set by the short exposures (2 seconds) .

exectuted that work in April 2012 and anticipate System Characterization to resume on May 21st — in preparation for Acceptance Testing, now scheduled to begin in June. We expect the instrument to arrive at Gemini South in the first quarter of 2013.

By the end of March, the project reached a significant milestone: its first end-to-end images. These were taken with artificial light sent into GPI from the telescope simulator (with the light corrected by the AO system), then stabilized behind the coronographic mask by CAL, and finally recorded on the IFS. The left image in Figure 4 (see previous page) shows an IFS H-band image taken without the coronographic mask. The right image shows the same configuration but with the coronographic mask; the surrounding dots are there for calibration purposes. Note that we expect the light attenuation from the central core will be even higher now that the IFS has been remediated. Figure 5 shows the Contrast Ratio curve of the two measured images in Figure 4 using a Gemini telescope simulator. These reached a contrast of ~ 10^6 from 0.2 arcsecond outward. The Contrast Ratio will be remeasured once System Characterization resumes.

GRACES, GHOS, and the Long-range Plan

GRACES is a joint project with the Canada-France-Hawaii Telescope (CFHT) to bring high-resolution spectroscopy capability to Gemini (R=55,000 in star-only mode, and R=32,000 in star and sky mode). The first "prototype" phase is aimed at confirming experimentally the excellent throughput values determined in the theoretical analysis of coupling Gemini to the ESPaDOnS bench spectrograph at CFHT; sensitivity should be as good or better than Keck's HIRES performance for for wavelengths of between 600-1000 nm).

The optical fiber link between the two buildings (270 meters total fiber length) has been designed and is under procurement and some of the preliminary testing of the installation technique is also underway. Design work for the injection module from GMOS and coupling into the ESPaDOnS is also underway at HIA. We expect HIA to deliver the hardware by year's end and commissioning to be completed by February 2013. We also anticipate a release of the instrument for shared-risk usage in 2013A (no data reduction will be offered in this Phase 1).

GHOS is the future Gemini High-resolution Optical Spectrograph for Gemini South. The baseline instrument requirements include simultaneous wavelength coverage between 370-1000 nm with a resolution of 40,000 (20,000 to 60,000 goal). GHOS (and GRACES) were launched after a call for white papers in July 2010. Three teams (Anglo-Australian Observatory, Center for Astrophysics and Space Astronomy, and HIA) were selected in October 2011 to work on conceptual designs for six months. At this stage, we are exploring both fiber-fed, bench-mounted, and Cassegrain-mounted designs.

An internal and external committee will hold a conceptual design review at the end of May. We expect this to lead to a down-select of a single team to carry on with the rest of the design and building of GHOS. If, however, the studies reveal that it's simply not practical to build such an instrument for Gemini (a long fiber feed sacrificing blue throughput, or a Cassegrain instrument needing to overcome flexure), we may cancel GHOS altogether. Additionally, if two teams offer compelling evidence that the instrument can be built, but both teams need further development, we may continue the competition into the preliminary design stage. We hope to receive a finished GHOS by mid-2015, but a more definitive schedule will have to await the results of the current design studies.

As part of defining the Gemini instrumentation long-range plan, we have initiated several actions jointly with our Science and Technology Advisory Committee (see article on "STAC" in this issue). First, we have defined a proper process with inputs, steps, and outputs, which we've linked to various events happening this year: For example, the Gemini North Adaptive Optics workshop in June, and the Gemini Science Meeting (GSM) in July, as well as other regular governance bodies meetings. The goal is to define the scientific capabilities needed by the observatory in 2020 and beyond.

Meanwhile, we need to decide which instruments will be preserved during our 2012-2013 transition to the 4+AO plan (adaptive optics bench and four instruments kept in operations). We also need to consider what suite of instruments should be built to meet the scientific needs of our broad community. We have recently made a call for white papers on a multi-wavelength, medium-resolution spectroscope (so-called the Gemini InfraRed Optical Spectrometer (GIROS)) as part of this exploration process.

Our long-range plan is an extremely important activity to keep Gemini competitive, and at the same time complementary, with other existing facilities. It is also a challenging process to map out all the variables and scenarios in creating such a bright future. We anticipate receiving enough feedback from the community, in particular at the GSM in July, to optimize the process and outcome. In parallel, we are developing new communication tools to provide the user community with more regular (quarterly) updates and news which will be distributed through our National Gemini Offices. We encourage you to contact us if you have questions.

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