June 23, 2003

Dr. Wendy Freedman, Director
Carnegie Observatories
813 Santa Barbara Street
Pasadena, CA 91101

Dear Wendy,

On June 2, 2003, the IMACS Pre-Ship Review Committee met at Santa Barbara Street to review the status of the Inamori-Magellan Areal Camera and Spectrograph, IMACS, to consider its readiness for shipment to Las Campanas, and to review plans for shipping, installation, and commissioning. The IMACS team greatly appreciates the careful, thorough job done by the Committee. The team has carefully reviewed an acted upon the Report of the Committee that you passed on to us two weeks ago. It is our opinion that we have dealt with the three major, and most of the minor, issues raised by the Committee that led to their recommendation of delaying the shipping of IMACS by of approximately two months. What follows is a report of the progress that has been made that leads us to recommend to you that IMACS be shipped on July 12th (a week later than originally planned) and installed during the August bright run as presently scheduled.

The Pre-Ship Review (PSR) Committee raised a number of issues leading to a recommendation that work continue on IMACS in Pasadena for an additional two months – both the Project and the Committee agree that work that requires extensive use of the shop facilities is better done at Santa Barbara Street than at Las Campanas. The three principle areas of concern were (1) elimination of internal light sources and testing for light leaks when IMACS is enclosed with its panels; (2) further tests of the optics, in particular, the difficulty with the f/2 camera focus; and (3) the development of a procedure for changing the CCD dewar between the f/4 and f/2 cameras that subjects the CCD mosaic array to minimal thermal cycling and does not discharge the Cryotiger cooling lines. A number of less critical items, also cited, are discussed below, including a schedule for the IMACS commissioning plan.

The first item of major concern cited in the PSR report was the elimination of internal light sources in the instrument and the possibility of light leaks through the panels that cover IMACS. None of this work had been done before the PSR. In the weeks since, we have successfully masked the numerous LEDs in IMACS, through the use of either aluminum tape or black plastic caps made in our shop, as appropriate for the different types. We decided that, with the exception of the two Renishaw encoders that are used to actively control the Principle and Shack-Hartmann guiders, the remaining encoders can be powered down after use: this includes the mask server, filter servers, disperser wheel, and grating tilts – the additional hardware switches and software for this modification have been completed and tested successfully. Combining these steps we were able to reduce the internal light sources to < 10 cts/hr/pixel, which was added to a comparable background level in the refrigerator box when IMACS is completely powered down. This remainder light is longward of 6000 angstroms and comparable to the dark current of the CCDs themselves.

Testing of the effectiveness of the enclosure panels to exclude stray dome light or moonlight is more problematical, since we do not have a good way to reproduce the seal of IMACS to the telescope's Nasymth rotator. However, we were able to verify that, with the exception of some "joints" in the flanges to which the panels seal, which must be calked, the panel system is effective. The seams along the panels very well, leaving only small openings at the ends of the panels where the flanges and panels come together. We are looking at several possibilities to plug these holes, probably with some type of weatherstripping or sheet metal cap that covers the end joint, but the obliqueness of the light path is such that any form of additional shielding should be sufficient. In a well-illuminated dome we expect IMACS to show excess background, but we believe that we can reduce the leakage during observing conditions to our goal of ~5 counts per hour per pixel.

As we reported at the PSR, the f/2 camera produces images as good as expected (~2 pixels FWHM over the full field), but focuses approximately 0.5 mm closer than expected. After investigating a number of options with Harland Epps, we were able to solve the problem by relieving areas of the dewar mounting plate that now permit the CCD mosaic to travel the needed amount. Since the total travel of the flexure stage that carries the CCD mosaic is limited to around 2 mm, we will be making a new, thinner "spectroscopic filter" for the f/4 camera that will put us in a comfortable focus range for both cameras, including temperature compensation for the f/4 camera. We have obtained small-step focus sequences for both cameras in all filters and verified the ~2 pixel or better performance at all wavelengths and have also verified the performance of both cameras in spectroscopic mode at 350-400 nm and 950 nm. The IMACS team intends to continue to analyze the possibility of small adjustments to the tilt of the mosaic and/or the tilt of the movable element in the f/4 camera, but these final adjustments will be better done after IMACS is mated to the telescope with the ADC/corrector. We believe that the tests at Santa Barbara Street are now complete.

The gradient we showed at the PSR of the image size in the f/2 camera, which ranges from well under 2 pixels FWHM in the inner regions to up to 2.5 pixels in the corners (corresponding to 15μ to 30μ) appears to be both better-than-expected in the center and not-as-good as expected in the perimeter, but this gradient does not change as the camera is taken through focus. The effect is most pronounced in shorter wavelengths. Brian Sutin will work with Harland Epps to see if this behavior can be produced by tweaking the model, for example, small changes in the spacings of the elements that we could adjust. It is possible this image-size gradient is related to the 0.5 mm discrepancy in the focus, but regardless, the camera will deliver images better than 0.45" in excellent seeing over its full field, which is very close to design specification.

The third item of major concern was the procedure for switching the CCD camera between the f/2 and f/4 foci. The PSR Committee was in particular worried about the frequent thermal cycling of the mosaic array if the camera is allowed to warm up fully between changes. Although such thermal cycling of CCDs is not known to be a problem, the IMACS team agrees that a more rapid changeover in which the array remains cold is much preferred for this reason and as an operational advantage for setting up the next night's observations. At the PSR the suggestion was made of some added valving that would allow the system to be switched cold, but as we suspected, the manufacturer confirmed that this is not possible. However, they did assure us that, as soon as the pressure has dropped near to its off-cycle value, it is safe to disconnect the hoses without discharging the system. We found that this condition was reached at about one hour after the pumps were turned off. We have made three such disconnections successfully, although in one case one of the hose connections began to leaked when disconnected, but sealed after being temporarily reseated on the valve and then removed.

We believe that the changeover procedure we are devising will work best when the temperature of the cold head has also warmed considerably (this is essentially the situation we adopted before the PSR when we let the system warm up for ~8 hours). Presently, the thermal inertia of the CCD mosaic and its cooling straps prevent this from happening in a short time – of course, this is why, with a 1-2 hour shutdown, the CCD temperature changes by only 10-20 degrees, which eliminates the thermal cycling of the array. In order to allow the Cryotiger head to warm up separately we are investigating a "thermal switch" inside the dewar, commonly used in IR detectors, that will break the thermal connection between the Cryotiger head and mosaic array during the changeover. This will result in little or no thermal cycling of the CCDs and a much higher temperature for the hose disconnect; we expect this to make the 1 hour shutdown + one-half hour for moving the Mosaic Camera a safe, routine operation. Should the thermal switch prove desirable, we will make this modification to the dewar in the field.

Actions on other items called out by the Committee.

- The distortion of the field lens has been measured at less than 2 pixels over the f/2 field through additional images of a grid of holes taken over a full rotation – this is as good as we can do with our irregularly illuminated pupil and indicates no serious problem.

- We verified that the optics and mechanics performed in extensive testing during T= 35-40 F and, in particular, found no failures of the air cylinder actuators in a three-hour test at T = 28 F.

- The dewar focus collar will be secured during a disassembly of the dewar mechanics in July at Santa Barbara Street – the dewar and mosaic CCD array will shipped at the end of July.

- We obtained a quote for interferometric measurements of the gratings and mirrors, but it was prohibitively expensive. We have looked for evidence of astigmatism over the field for the case of one of the mirrors, and found none. The gratings and mounts are supported quasi-kinematically, which means that no large forces should be transmitted to the glass, so this result is as expected.

- The multiplet in the f/4 camera will be repotted as IMACS is disassembled and will either travel with the instrument or with the dewar at the end of July. After considerable discussion, we decided not to risk the loss of L05, the CaFI element with the central "crazing," the deleterious effects of which should be quite minor. We believe it would be far more sensible to start from scratch to replace this lens, if this seems desirable or necessary.

- Shipping containers for the optics have been ordered from Anvil and Hardigg. These will be foam-lined and secured to heavy plywood platforms that are shock mounted to the shipping container.

- Ken Clardy is now in Chile working with the LCO team to iron out the final wrinkles of the laser mask cutting system, and Pat McCarthy and Dressler are de-bugging Ken's software for mask-making using a wide-field of 1000 objects from the deep IR survey.

- Development will continue on the software and hardware for closed loop control. Simulation of observations with open loop control has now been done at both cameras: typical exposures result in 0.2-0.4 pixel drifts although an occasional ~1 pixel drift has been observed. This level is sufficient for almost all observations. Plots of some of these data are attached to this report.

- Thermal management of IMACS will be investigated at the telescope.

Concerning the commissioning of IMACS, Dressler and Oemler reviewed the order and duration for each task and subdivided the tasks into the available dates. The total estimated time is 10 days and 11 nights, which suggests that two shifts may be necessary when both days and nights are available. Although such forecasts are always optimistic, we have done our best to inject some degree of realism. This list is appended below.

After a discussion of the Committee's final recommendation concerning the scheduling of IMACS for use by other astronomers, we recommend that any action that alters the present schedule be deferred until the end of August, at which time the status of the instrument will be much better known.

Again, we would like to extend our thanks to the PSR team for their very instructive comments and advice. To you, Gus Oemler, and everyone at the Observatories, we would like to express our deep appreciation for the unwavering, enthusiastic support and encouragment over the last four years.

For the IMACS team,

Alan Dressler

IMACS Commissioning Activities:

August 6-12: Basic reassembly of IMACS mechanics
Fit-up and test of CCD Mosaic camera

August 13-15: revalidate mechanical devices, function and flexure of individual components. Test Nasymth instrument rotator and link to IMACS. Verify internal dark level achieved in Pasadena; work on panel seams and sealing to Nasymth rotator.

August 16-20 (immediately after 10-day installation)

Day 1-2: Re-establish internal optical performance achieved in Pasadena, using grid-masks. Finish aligning mirrors, gratings, grisms, and rotation of f/2, f/4 cameras (preliminary work done in Pasadena). Develop final disperser tables: central wavelengths of grisms, wavelength ranges of gratings as a function of tilts.

Night 1: Check telescope-to-IMACS alignment
Focus telescope to Centerfield guider (CF) slit
Focus the Principle (PG) and Shack-Hartmann (SH) guiders, move them to check for tilts or skews – shim if necessary

Nights 2-3 Calibrate CF Shack-Hartmann, referencing to East-port unit
Calibrate (off-axis) SH guider, referencing to CF – check sensitivity to small radial motions of SH guider; check for insensitivity to angular sweep

Night 4: Take sample exposures, some deep, with f/4 camera, imaging and spectroscopy. Confirm target acquisition, alignment, and guiding. Check for scattered light in imaging and spectroscopic mode. Measure throughputs. Test CF slit-viewing guider – take high resolution spectrum of a bright object.

Night 5: After moving camera to f/2 focus, repeat night 4.

September 11-13 (following the installation of Corrector/ADC)

Night 1: Starting with f/4 camera, measure optical performance of system. Measure scale and distortions. Make first observations with IFU. First attempt at multlislit spectroscopy. Measure throughputs again, especially important to determine UV performance of corrector for f/4.

Night 2: Repeat night 1 with f/2 camera

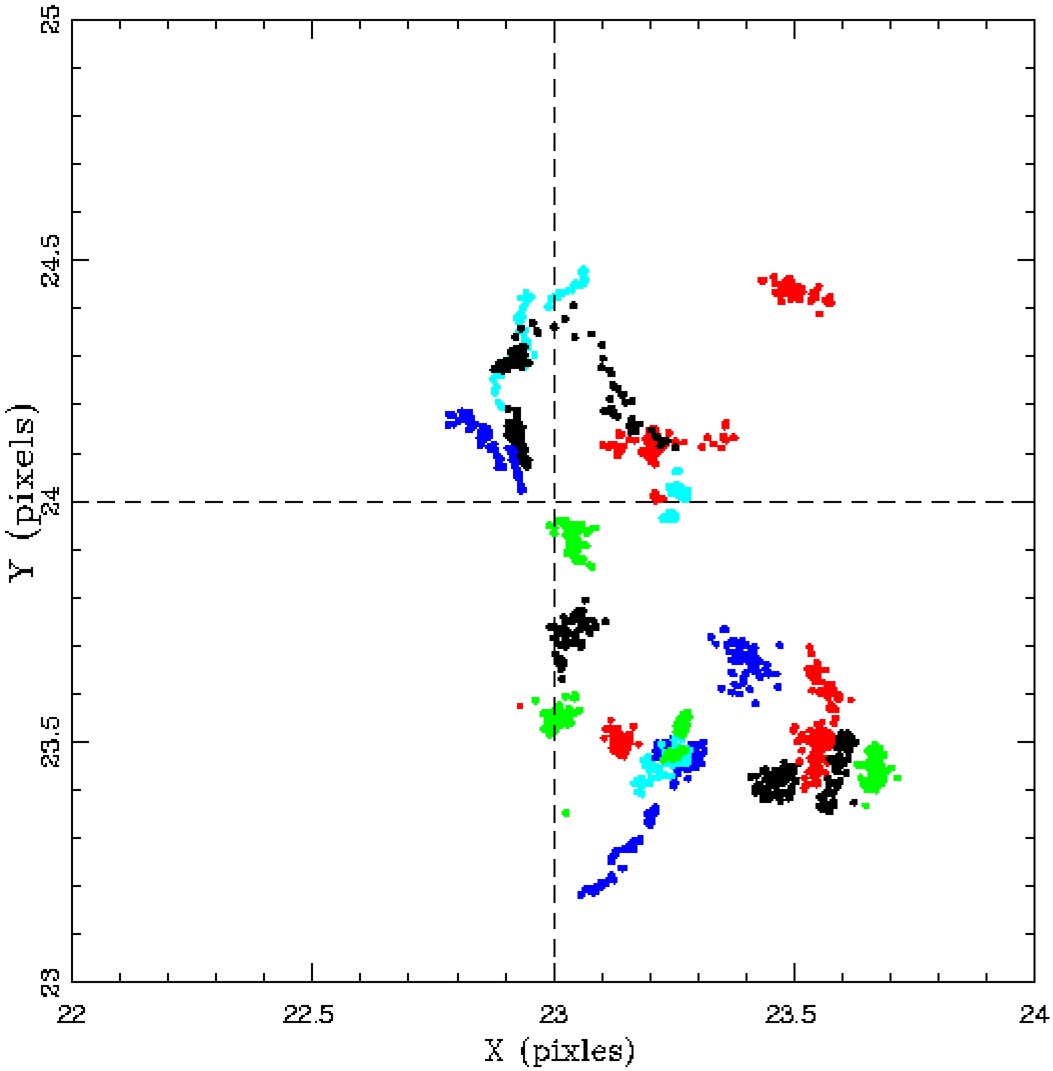
Night 3: Continue with development of multi-slit observing modes.

September 17-21: dark run

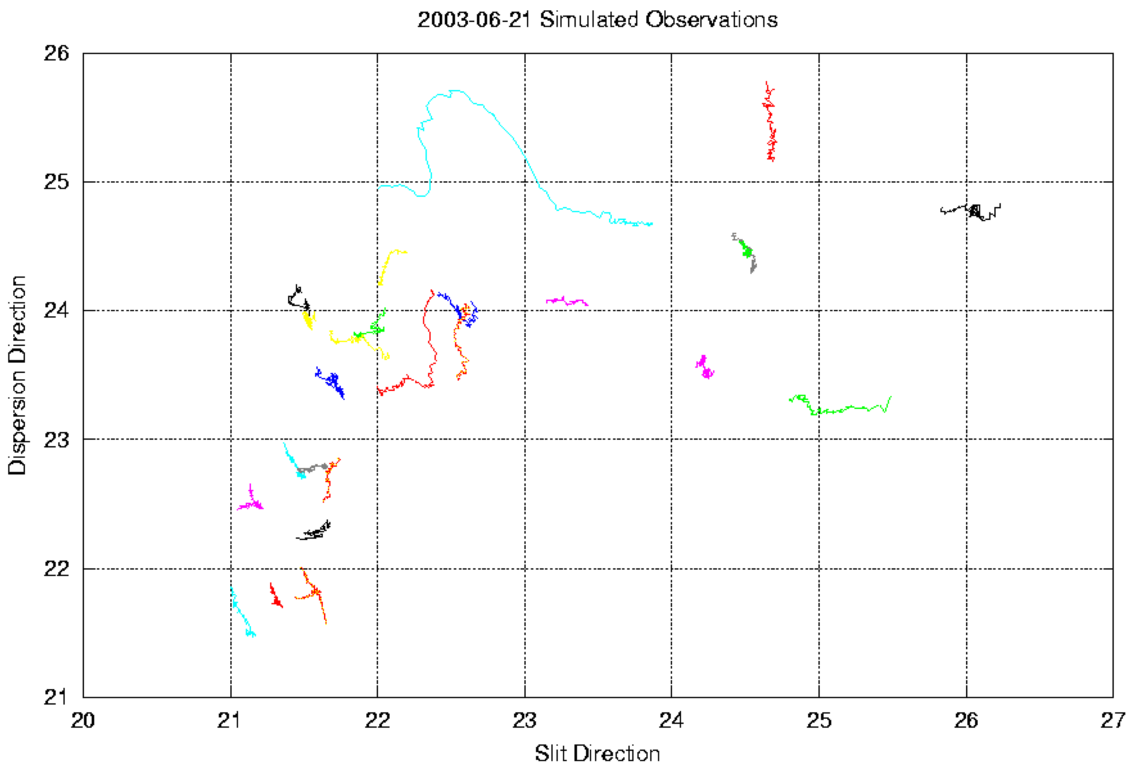
Continue testing of items specified above. Implement corrective measures or parts resulting from previous testing. If above tasks have been largely accomplished, work on multislit spectroscopy, developing the nod-and-shuffle mode in particular. If the Echellette is available, it will be tested at this time. Work with LCO staff to develop protocols for making slitmasks, changing gratings and filters, changing CCD camera between foci. Begin science observations of various modes submitted by Carnegie astronomers, as permitted.

October 15-29: first regularly scheduled observations with IMACS

Eight of these are Carnegie nights that are available for further commissioning, by agreement of Mulchaey and Rauch, and 4 more nights assigned to Chilean astronomers may be available as well.



These are data from a two-night simulation of observing with the f/2 camera and the 300 l/mm grism. For each observation IMACS was slewed to a new position representing a random position in the southern sky, followed by 50 minutes of "tracking" at the proper speed. Open-loop flexure control was used. The grism was unlatched and relatched between exposures. The system shows excellent repeatability and sub-pixel drifts during exposures.



This is an equivalent test of the f/4 camera with the 1200 l/mm reflection grating. The brake that has been installed to steady the wheel while the latchup occurs has improved the repeatability, but there is still a quadrant of rotation when the image shifts by 3-4 pixels. In addition, there are some instances of significant wander during an exposure. Although this performance is acceptable for beginning observations, we will continue to investigate and refine the operation of this system.