MMT Observatory
Smithsonian Institution &
The University of Arizona®

# End of Quarter Summary

## January - March 2016

## MMT Observatory Activities

Our Quarterly Summary Reports are organized using the same work breakdown structure (WBS) as used in the annual Program Plan. This WBS includes a major category with several subcategories listed under it. In general, many specific activities might fall a tier or two below that. The WBS will be modified as needed in future reports.

## Administrative

### Program Management

The following meetings were held during this reporting period: one engineering, one electronic, two cell crate, and two senior staff.

MMT Council meetings were held on February 8 and March 28.

R. Ortiz traveled to SAO in Cambridge, MA during the last week of March to discuss the status of the Binospec instrument and its planned delivery to the MMTO later this year.

### Staffing

M. Alegria became Assistant Mountain Operations Manager on January 4. He continues as Instrument Specialist.

D. Gerber, Electrical Engineer, accepted another position and her last day with the MMTO was January 8.

Site visits were held in January and February with four candidates for two Queue Observer positions. Offers were made and accepted by Chun Ly and ShiAnne Kattner. They will start in September.

Interviews and site visits were held March 16-22 with four mechanical and three electrical engineering staff candidates. One each will be hired as Staff Technicians.

## Reports and Publications

There were 14 peer-reviewed publications and one non MMT-related publication during this reporting period. See the listing of publications in Appendix I, p. 28.

### Presentations and Conferences

R. Cool and J. Hinz attended the 227$^{th}$ American Astronomical Society (AAS) meeting in Kissimmee, Florida on January 4-8. They staffed the first MMTO exhibit booth at an AAS meeting.

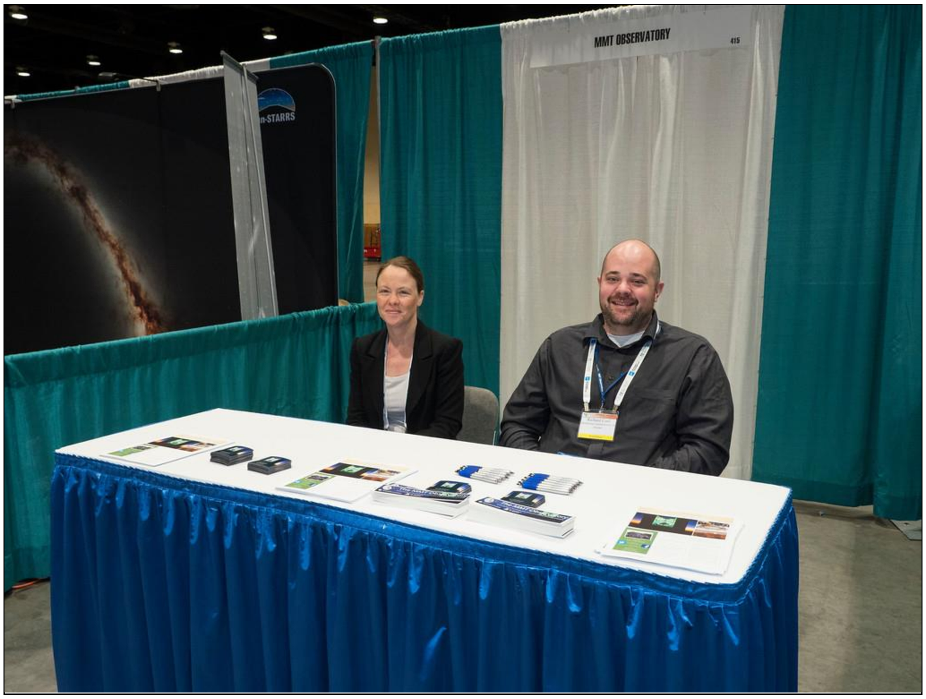


Figure 1. J. Hinz and R. Cool shown at the MMTO table at the AAS meeting.

## Safety

### Training

Mountain staff members attended a "Slips, Trips, and Falls" training held March 23 at the F.L. Whipple Observatory (FLWO) Administrative Complex.

### Interlock System

In late February there was a problem with E-stop in the 26V rack being triggered, halting telescope operations. The cause was tracked to a loose connection in the telescope operators' paddle. This led to the discovery that some documentation for the 26V E-stop chain was incorrect. The E-stop chain was thoroughly traced out and the documentation updated.

Current and former electronic staff went through all of the 26V rack documentation to bring it up to date. Upon completion, it was added to the documentation database. A copy was also printed and added to the binder located near the rack.

## Primary Mirror

There was a problem with the cell crate power supply not initializing upon startup until the reset button was manually pushed. The cause was found to be a bad cell crate CPU card. We believe this was also causing some of the recent actuator failures. Although these failures have decreased, there are still occasional actuator failures requiring further troubleshooting.

A new spare cell crate power supply was completed and tested, making two complete cell crate power supplies available. However, the original power supply will continue to be used until more in-depth testing can be completed on the new spare.

### Coating & Aluminization

Progress was made towards performing a full scale test of the primary mirror (M1) aluminization system at base camp. Presently the first test is scheduled for early May.

Leveraging the experience acquired from the control system testing at the Sunnyside testing facility, the aluminization control software has been reworked in order to improve the reliability and supportability of the aluminization system. The previous version of the software used Simulink generated to code to step through the filament heating process. Transitions through the process steps were driven by sensor measurements and time in each specific state. While the state machine style software was helpful during the development of the filament heating curve, a preferred curve has now been established, and all subsequent coatings should follow this heating profile. Hence, the software has been rewritten to playback the welder setpoint required to produce the desired heating curve. For simplicity, the playback script will run open loop, and the process safety checks will be performed primarily by a human operator. An additional benefit of the playback script is the straight forward implementation of a dedicated welder setpoint curve that can be used to test the control system operation using the load resistors. Load resistor testing will be the final end-to-end system test performed before connecting the welder and feedback cables to the bell jar.

The following pieces of software were developed to accomplish the playback/open loop filament control

1. AlumDriver is a compiled C driver that has been written to reliably interface with the three PCI data acquisition boards in the aluminization PC. Any unit conversion or other calculations take place within other pieces of software, primarily AlumRelay.
2. AlumRelay is a server application written in python that subscribes to the raw data provided by AlumDriver. AlumRelay handles all of the unit conversions, parameter computations, system status monitoring, and welder enable/disable process. AlumRelay is based on a "configuration file" model, and almost all of the system parameters can be modified in the single configuration file. After modification, AlumRelay only needs to be restarted in order to implement the changes. Hence, the software does not have to be recompiled in order to implement minor changes, such as slight adjustment to the gain or offset values of data channel.

The new pieces of software were implemented to provide the same interface as the previous software, so the existing Node.js graphical user interface (GUI) server has remained unchanged.

A significant portion of time was spent in the MMTO electronics lab using a single welder to develop the revised software approach. Included in this was the creation of a straight forward GUI to enable/disable and to monitor the welders (Figure 2). This browser based GUI operates in addition to the traditional aluminization control GUI that was used during Sunnyside testing. This GUI provides the ability to individually enable each of the ten welders for troubleshooting purposes. Additionally, this GUI will enable the welders in pairs (corresponding high/low welders) with a few seconds delay between each pair. Once all of the welders have been enabled and the currents and voltages are within range, the “Playback” button of the GUI will be activated, and the operator can proceed with the filament heating process.

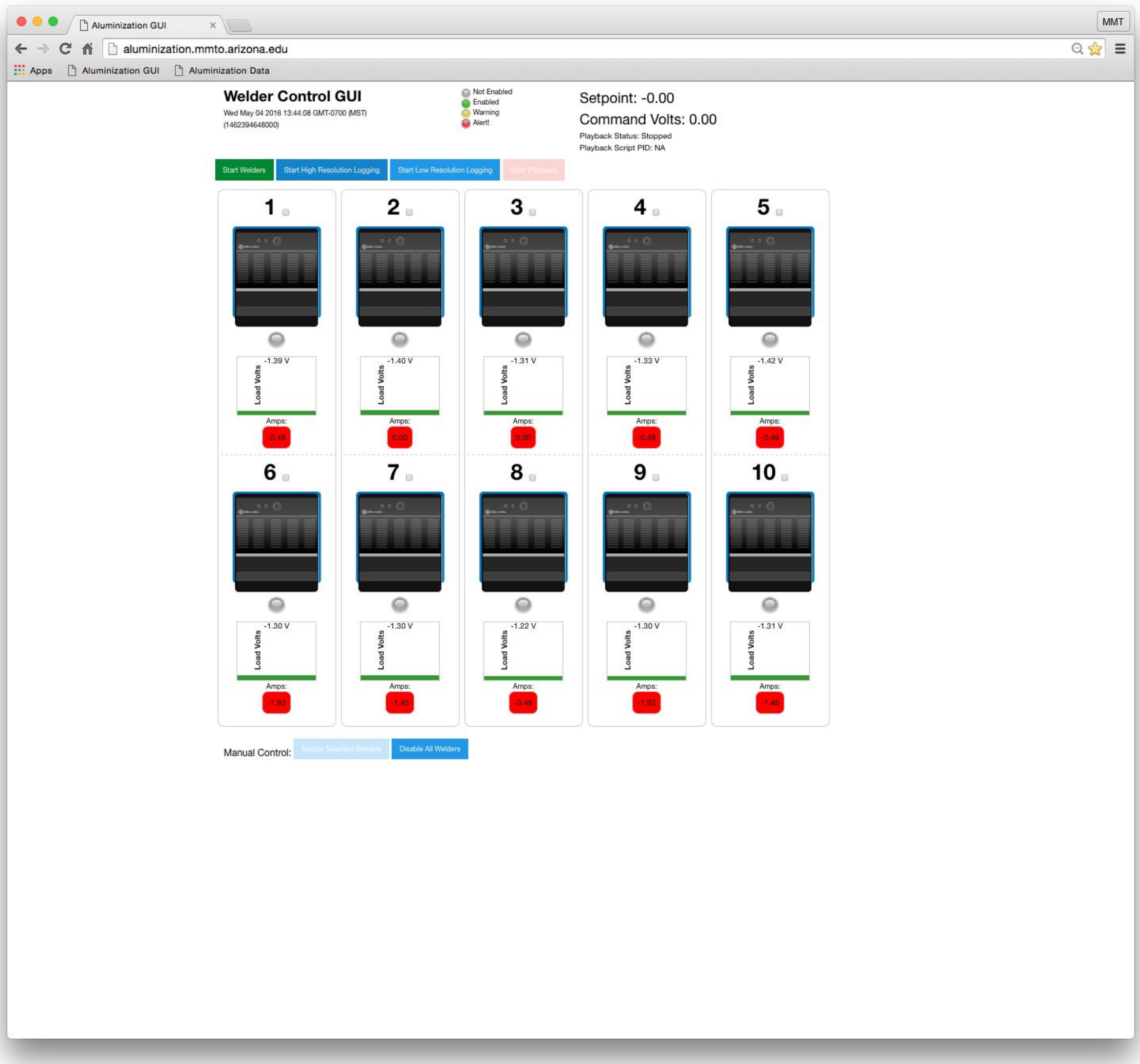


Figure 2. New welder control GUI

In February, the bell jar was loaded with the new 13 H filaments (Figure 3). In the process of removing the old filaments, roughly twenty of the tapped holes used for the filament holders were damaged. Various methods were developed to repair the damaged holes. In some cases, the thread damage was minimal enough that the threads could be chased and a slightly longer bolt could be installed. For some holes with more damage, a stud and nut were installed in place of the original socket head cap screw. In only a single case was the damage severe enough that a threaded insert was required. Since the damage to the threads is occurring due to the use of stainless fasteners in aluminum tapped holes, a number of damaged tapped holes is to be expected any time the filaments are removed or installed. When appropriate, clean black oxide fasteners are being installed in place the stainless socket head cap screws. After the new filaments were installed, the electrical resistance of the arrays was measured using a milliohm meter; no electrical shorts or other issues were observed during these measurements.

Figure 3. R. Ortiz and C. Chang positioning the lift to start filament installation.

The new turbo backing pump was tested in the assembly bay at base camp. In the blanked off condition, the pump quickly reaches a base pressure of $1x10^{-3}$ Torr. A pump saver valve and an oil trap have been installed on the backing pump; this is in preparation of testing the V6000 turbo pump in the assembly bay. This testing is expected to be completed in early April.

A 480V to 208Y/120V transformer and associated breakers and disconnects have been installed near the bell jar. Previously, only 480V power serviced the bell jar area at base camp. This service was sufficient to operate the pumping trailer, but the turbo pump and aluminization control system require 120V power.

The small Sunnyside coating chamber (18") was converted from a filament test chamber to a single axis M1 actuator testing station (Figure 4). To evaluate the possibility of leaving the M1 actuators in the cell for the next M1 aluminization, two single axis actuators were vacuum cycled in the small Sunnyside chamber. Before being sent to Sunnyside, the actuators were checked out on the test stand. Each actuator was placed in the chamber without the electronics card and pumped down to 50 milliTorr. This vacuum was maintained on the actuators for 60 minutes. After this round of vacuum cycling, the actuators were operated again on the test stand. No issues were observed for either cylinder. The actuators were sent back to Sunnyside for another round of vacuum cycling. For this testing phase, the actuators were each held under 50 milliTorr for 180 minutes. The actuators were tested again on the test stand, and one actuator passed while the other failed. The failure was traced to the sealant on the pressure relief valve threads becoming displaced and stuck in the narrow passages of one of the control transducers. The pressure relief valve is removed each time an actuator is tested on the test stand, so most likely, this failure was not related to the actuator being vacuum cycled. The control transducer has been cleaned, and the actuator now checks out on the test stand. With a modified test stand procedure, these single axis actuators will be vacuum cycled one more time at Sunnyside before a decision is made regarding the removal of the M1 actuators from the cell for the upcoming primary mirror coating.

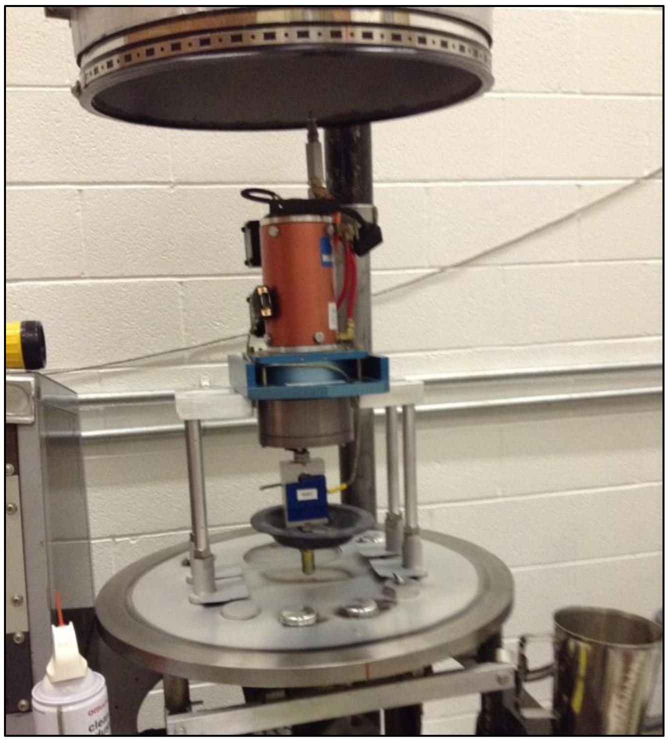

Figure 4. An M1 single axis actuator in the small Sunnyside chamber.

New DAC cards were ordered for the isolation amplifier used for aluminization. It was determined that the wrong size tantalum capacitor was being used, causing the cards to burn up (a 16V capacitor was being used while 24V was fed to the card for operation). Three new cards were populated and operationally checked. One of the new cards was installed.

**Ventilation and Thermal Systems**

The southeast Type T thermal enclosure was completed. A final absolute card was installed and the system is now fully operational. Data has been collected and shows a correlation between the Type E series thermal system and the Type T thermal system. Data will be analyzed to compare the two outputs and evaluate the delta of the two.

A revised version of the automated primary mirror ventilation system software ("vent_auto2") was deployed in March. This version uses a portion of the control logic and safety checks from the existing ventilation system control code ("vent_auto"), which has been used since 2009. Major differences from the previous version of the code include the incorporation of new HVAC hardware and changes in control logic, particularly under warm outside temperature conditions. The control logic changes are required so that glycol reaching the new HVAC fan coil units (FCUs) is always at or below 10°C/50°F. Cold glycol is required for the FCUs to work properly.

Conversion of Carrier chillers to BACnet has been more difficult than originally anticipated. Deployment of the OpenUPC Carrier Comfort Network (CCN) to BACnet communication module for Carrier2 was delayed because of internal alarms within the chiller, preventing it from operating. These issues have been resolved. Use of a similar OpenUPC module on the older Carrier1 was delayed because of firmware incompatibility issues with this 19-year-old chiller. Several versions of OpenUPC firmware were tested before basic control of the Carrier setpoint could be achieved. There were also issues with the wiring at the front panel. An old version of the OpenUPC firmware that gives access to some CCN parameters is now in place for Carrier1. The current versions of OpenUPC firmware allow Carrier2 to be turned on or off remotely, while this functionality is not available for Carrier1. The vent_auto2 software was modified so that it allows Carrier1 to operate either with the existing obsolete DataLink module or through the new BACnet OpenUPC module. Communication with Carrier2 is only through BACnet.

A major change during the HVAC upgrade is the method in which glycol circulates through the shop and pit heat exchangers (see Figure 5). Previously, all glycol flow went directly through each heat exchanger. In the revised plumbing, glycol can be regulated with a Belimo valve to bypass each heat exchanger from 0% (*i.e.*, no bypass) to 100% (*i.e.*, complete bypass). The shop and pit Belimo valves are controlled via BACnet with a commanded value of 0.0 (0% bypass) to 10.0 (100% bypass) with command resolution to 0.1 units. Glycol flow control with these Belimo valves allows finer control of glycol temperature and the associated ventilation air temperature.

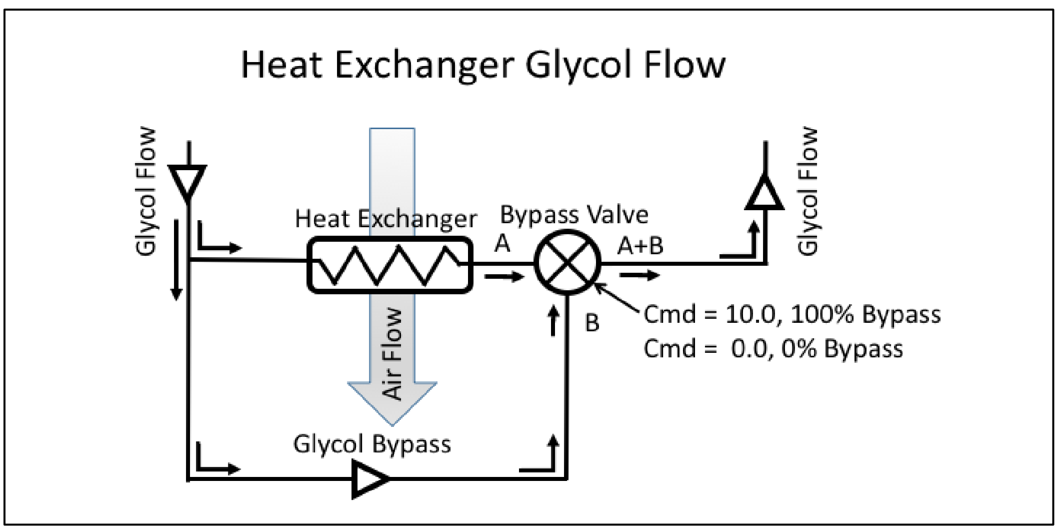


Figure 5. Schematic diagram of glycol flow through the shop and pit heat exchangers. A Belimo bypass valve was installed for each heat exchanger during the HVAC upgrade that allows glycol to flow either through the heat exchanger or around (*i.e.,* bypass) the heat exchanger.

In its current state, vent_auto2 makes changes to the Carrier setpoint in a manner similar to that of the vent_auto code when the target ventilation temperature is between -10°C to 10°C. The pit Neslab is still required for target ventilation temperatures below -10°C. For target ventilation system air temperatures above 10°C, the shop bypass valve is slowly opened, reducing the cooling efficiency of the shop heat exchanger. The pit bypass valve is continually being used to trim the ventilation air temperature towards the target air temperature. At the moment, the pit Neslab is also being used to help trim the air temperature. Data from numerical sensors within the upgraded HVAC system is being logged into relational databases for further analysis and for refinement of the control algorithms.

Modifications were also made to the HVAC control GUI (Figure 6) to match the changes in BACnet parameters to reflect the different versions of hardware firmware. Control of the pier, the yoke room, and the trench fans as well as the perimeter heaters, has been incorporated into this GUI, eliminating a separate fan control GUI.

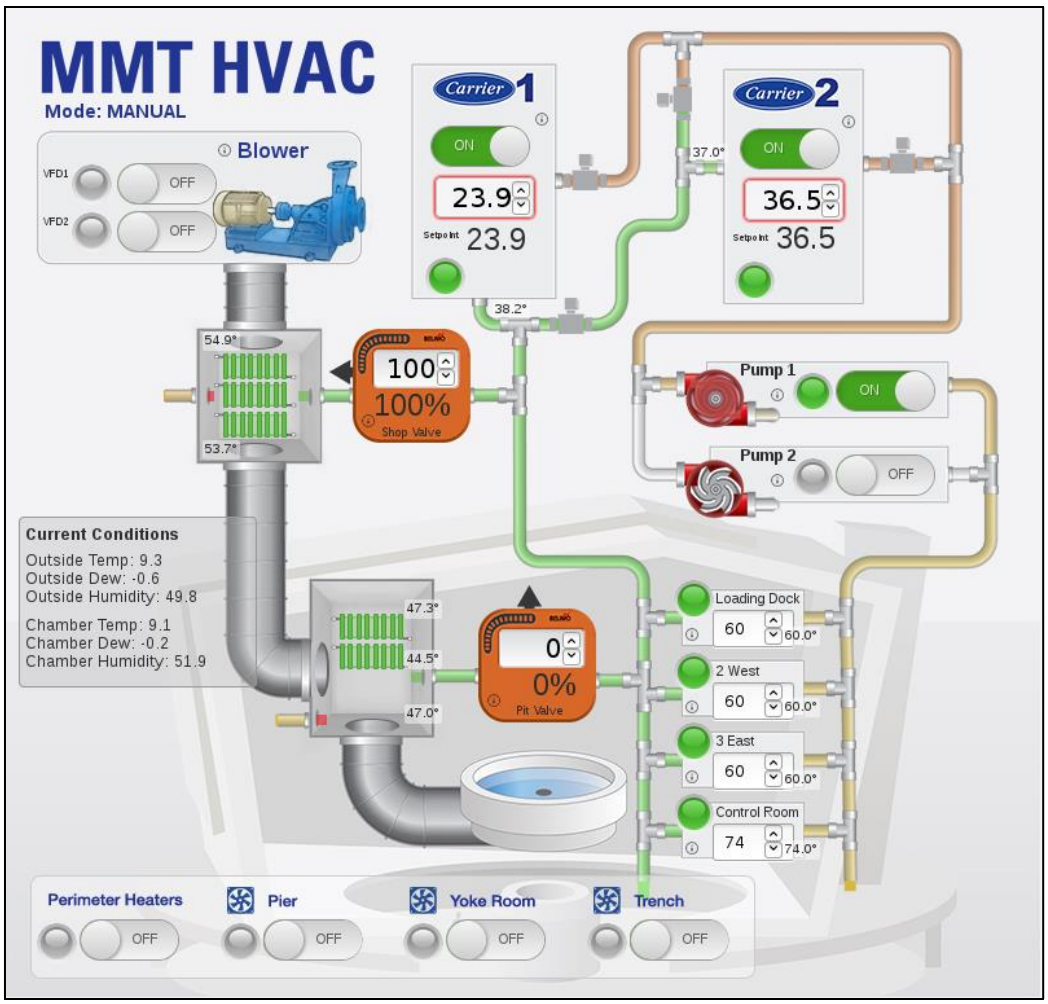


Figure 6. Modifications were made to the HVAC control GUI to include the perimeter heaters and the pier, yoke room, and trench fans. A separate control GUI for these fans is no longer needed.

### Actuators

All fully populated spare actuator cards were tested. Three cards were repaired and put back into service. Two of the cards were determined to be not repairable.

## Secondary Mirrors

### f/5

Odd oscillations were reported in the f/5 secondary in late January. The mirror support cards were swapped out and sent to the campus electronic shop for inspection. An integrated circuit (IC) was found to be loose. After a thorough inspection and reseating of chips, the card was placed back into service.

## Hexapods

Nothing to report.

## Optics Support Structure

Nothing to report.

## Pointing and Tracking

Nothing to report.

## Science Instruments

### f/9 Instrumentation

The f/9 instruments were on the MMT for 31% of the available nights from January 1 through March 31. Approximately 71% of those nights were scheduled with the Blue Channel spectrograph, 25% with Red Channel, and 4% with SPOL. Of the 320.2 total hours allocated for f/9 observations, 146.38 hours (45.7%) were lost to winter weather conditions. Instrument, facility, and telescope problems accounted for 3 hours of lost time. Blue Channel lost 39.5% of its time to poor weather, with Red Channel losing 63.8%, and SPOL losing 46.4%.

An exposure time calculator for the Red and Blue Channel spectrographs was deployed to www.mmto.org/expcalc. The front end runs in PHP and Javascript. The calculations are completed in a python script feeding into a HighChart Javascript plotting module. The user is guided through entering each of the parameters for their observations, and some basic error checking is done before the user is returned to a simulated spectrum for a flat (F_nu) spectrum source of their specified magnitude.

The calculator has been verified against a handful of calibration spectra covering a range of instrumental setups. It does not support the Echellette mode for either spectrograph. Contributions from filters and the blaze function were created by using "plot-reader" software that allows "tracing" the existing plots in the MMTO webpages to a text file.

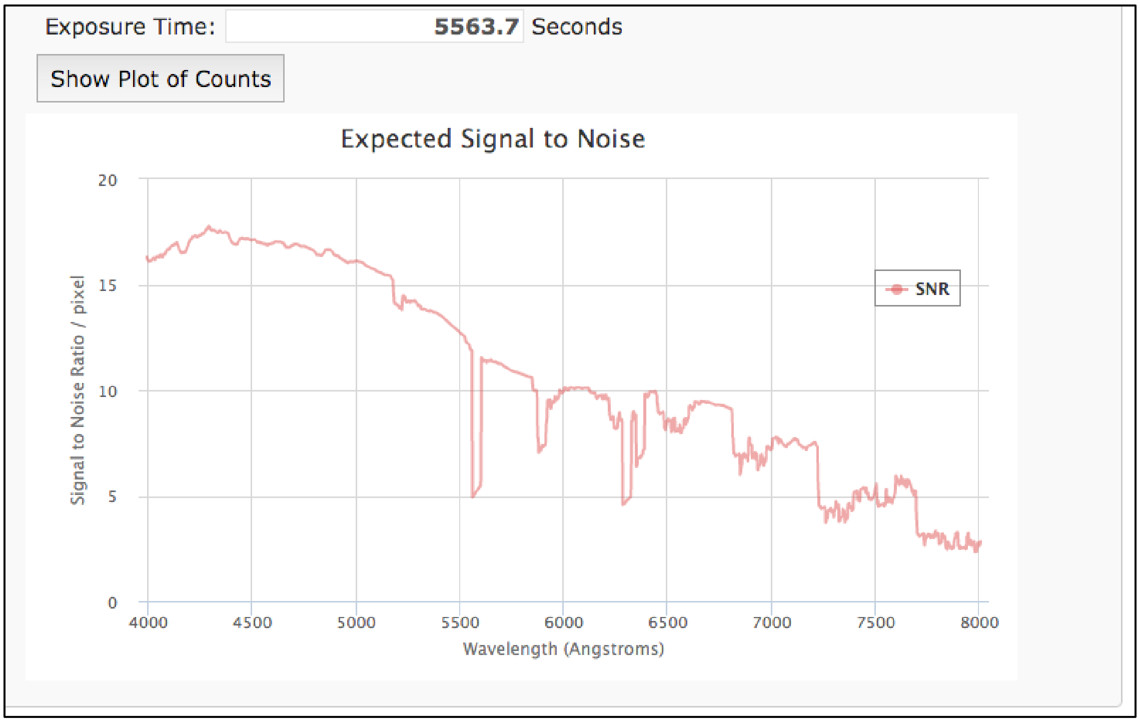


Figure 7. Expected signal-to-noise (per pixel) for an R=21 AB source observed for 5563 seconds (the needed exposure time to reach a mean S/N of 10).

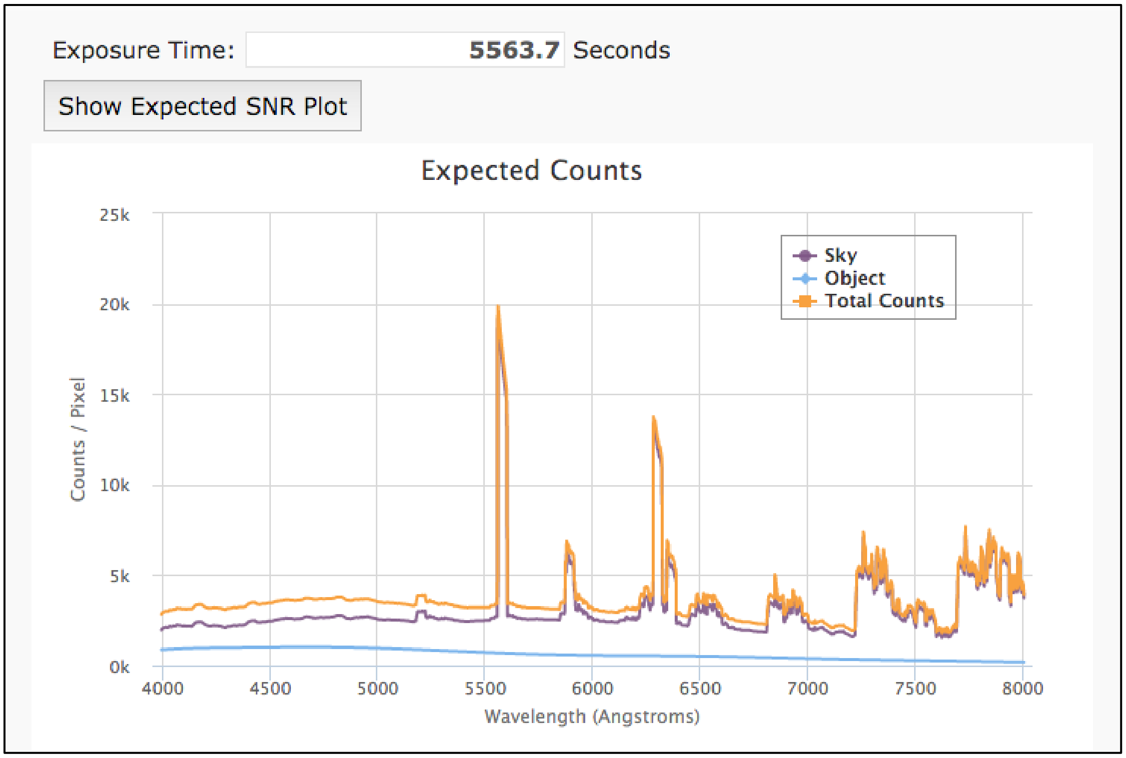


Figure 8. Expected counts per pixel for the total spectrum (orange), sky (purple), and object (blue) for a flat-spectrum 21 magnitude source observed for 5563 seconds. The user can understand the relative contribution of major sky features on their target.

We found that the throughput curves for each of the gratings was quite similar to that of the lowest resolution grating when scaled by pixel size and blaze contributions. Thus, the broad wavelength throughputs of each system are set by the low-resolution grating. This also means that corrections of the blaze angle are done relative to the correction in the lowest-resolution grating.

**f/5 Instrumentation**

The f/5 instruments were scheduled for forty-six nights during this quarter. Of the scheduled hours, only 16% were lost to weather. MMIRS was allocated fifteen nights: three in January following a run that had begun in December, and twelve nights in March, one of which was a Maintenance and Engineering (M&E) night. Twenty-five nights were allocated in part to HectoSpec, five nights in part to HectoChelle, and some MMTCam data was taken on approximately half of the thirty Hecto nights. Overall, it was a good quarter.

There were a few facility issues:
- a few minutes were lost to a power outage on 2/4
- a half hour was lost to a mirror panic on 3/19
- a quarter hour was lost to investigate why noise associated with building rotation became much louder on 3/22
- more than an hour and a half lost to a building LVDT issue on 3/28.

On the instrument side, an hour was lost on March 19 due to a MMIRS code feature that caused the beginning of night alignment to fail if the first observation was long slit. B. McLeod and I. Chilingarian were not fully aware of this feature. The MMIRS wave front Camera 2 Y motor issue from last quarter was investigated in January. No clear cause was found. We did discover that our 3U Compact PCI extender board has the same format but is incompatible with the PMAC cards. Some of the board grounds correspond to PMAC enable signals. The WFS2Y motor issue "fixed" itself after much testing and prodding of cables prior to instrument mounting in March, and then returned during the M&E night. B. McLeod and M. Lacasse were able to trace the issue to a deeply buried connector in the instrument rack and were able to get the connection much more stable. There was a repeat episode on March 27 that was quickly corrected. There was also a half hour lost to the Dekker wheel losing its position and failing to home on that night. We were unable to repeat the problem when exercising the wheel the next day, and the problem did not recur. A half hour was lost when the guide stars for a Hecto field were not in the specified location and could not be pulled in on February 8. A quarter hour was lost when the guider corrections accidentally turned off on March 14.

The MMIRS runs were much more productive this quarter with the better weather and fully functioning guide and WFS packages. There were 1241 object files on about 90 fields consisting of single-slit spectra, multi-slit spectra, and images. Supporting these were 3127 calibration files consisting of darks, alignment images, test images, flats, comps, and telluric comparisons.

There were 506 science exposures with Hecto Spec/Chelle on 49 objects. There were 684 calibration exposures taken consisting of bias, dark, and flat frames. We found that the T1 axis oscillations recur sometimes when the robots are stowed after guide-star acquisition, but the issue can be resolved quickly.

There were 487 science exposures gathered with MMTCam on 49 objects with 684 non-science frames consisting of bias, dark, and flat frames.

There were fewer computer issues this quarter. There was one spontaneous reboot on January 19 coinciding with a significant voltage drop when systems were being powered up in the afternoon. A system 76 computer was set up in January to serve as VNC host for MMIRS and Hecto, removing f/5 from p*ixel*, and it has performed well. A spare has been purchased to be used for Hecto service missions and was set up in 2 East. The fiber converter for WFS, which resides in the f/5 computer rack in 3E, failed again. We swapped to the backup unit and were quickly back online.

One of the Thorium Argon bulbs in the chelle can was replaced in January.

Work began this quarter on the designing and implementation of a queue observing system for MMIRS observations, with the intention of extending the framework to future queue observing instruments such as Binospec. Given the ever more complex nature of astronomical instrumentation, strong history, and gained efficiency of being able to tailor observing schedules to the current observing conditions, we expect that moving toward a queue-observed infrastructure rather than the past classically block-scheduled format will result in a marked increase in observing efficiency. While the system is still under active development, the current system was proven successful during the March MMIRS observing run, with some notable road bumps that served as learning experiences.

The addition of a "Phase II" step for astronomers is required in order to understand, explicitly, what observations are needed for each target in each scheduled program. At this time, the MMOST tool developed at SAO's Center for Astronomy (CfA) is utilized to collect the data for each target including position, instrumental setup, required conditions, and priorities for each target. This tool is not without its limitations; currently only one instrumental setup is permitted per object name, and duplicate object names overwrite the previous entry. For example, if an observer wanted J and H imaging of M31, they would need to submit observations for M31_H and M31_J – submitting both with the name M31 would result in only one setup being recorded. Creating a database-driven web interface for the collection of Phase II details should be a high priority goal moving forward with the queue design.

The algorithm behind the queue decision making is based heavily on the system used for the Hectospec, Hectochelle, and MMTCam instrument. The key goal of the scheduler is to strive to keep the ratio of allotted time to allocated time as close as possible between programs. The scheduling is done in an iterative method where the ratio between total scheduled time and allocated time is used as an additional weight when choosing programs to be scheduled in the next iteration. We find the algorithm reaches a stable point in 4-5 iterations in most circumstances.

In detail, the queue backend takes as input a listing of each date in the observing block and the program each night was assigned to, including the fraction of the night for non-full allocations. This sets the totalTime allocated to each PI. We then calculate the ephemeris for each night in the observing block and the observability, airmass, lunar brightness, and lunar distance for each target in the submitted Phase II information for each night in the run. We fill each night subject to a number of weights that describe how well a given observation fits into the window, and a weight that includes the amount of time each program has been scheduled compared to its totalTime. When ties arise, currently the system randomly chooses between tied programs. A needed improvement is a better tie-breaking method based on previously obtained data, external priorities, and mask change limitations.

The queue is communicated to the queue observers by an MMTO staff scientist. The schedule is displayed in a web interface that graphically lays out the plans for the night and summarizes the full details of the observing parameters for each field. The final, and possibly most important, improvement will be to allow the queue observers to interact with this schedule in such a way that they can report good observations that are completed during the night. Currently, a staff scientist checks the logs from the previous night each morning, edits a text file containing the fields that were observed, and re-runs the queue with the updated "done" exposure list. Revising this process to require fewer steps the next morning, and making it part of the observing process for the queue observers, will greatly increase efficiency as well as eliminate several sources of error.

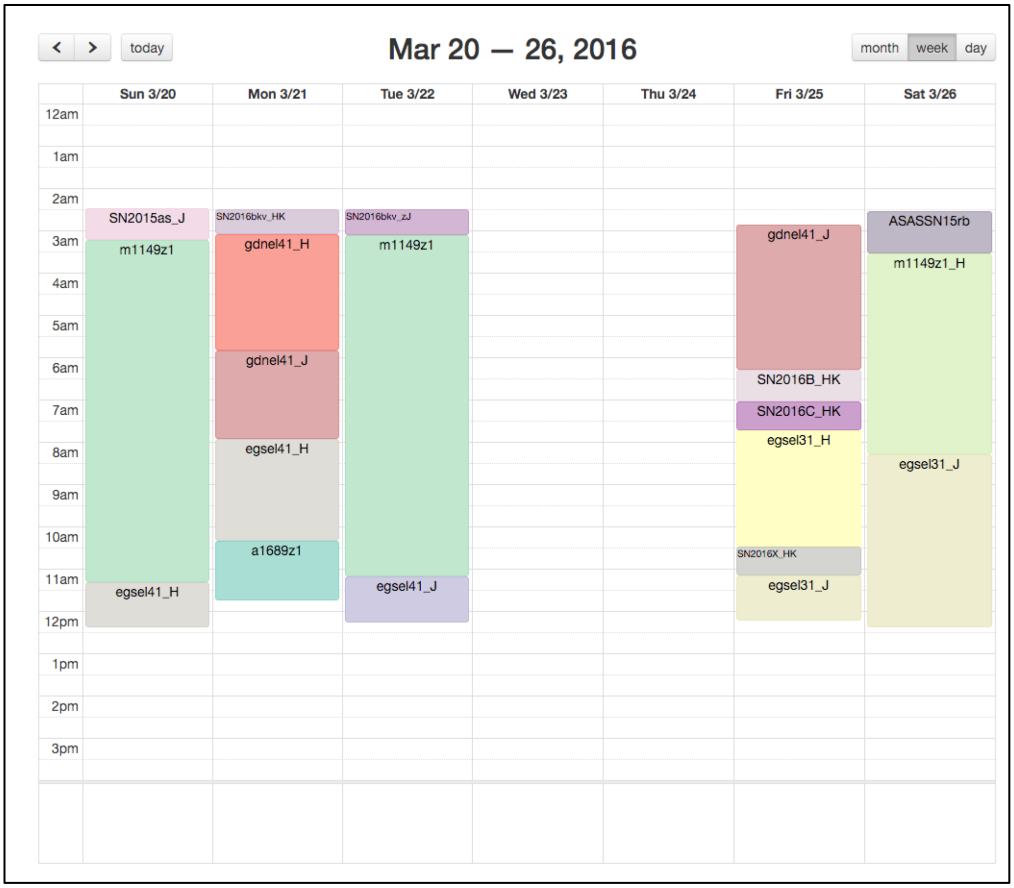


Figure 9. Block schedule view of the MMIRS queue from March. This view allows queue observers to visualize the plan for each night of the week. Navigation can occur at the top of the schedule to move forward week-by-week, or view a full month at once.

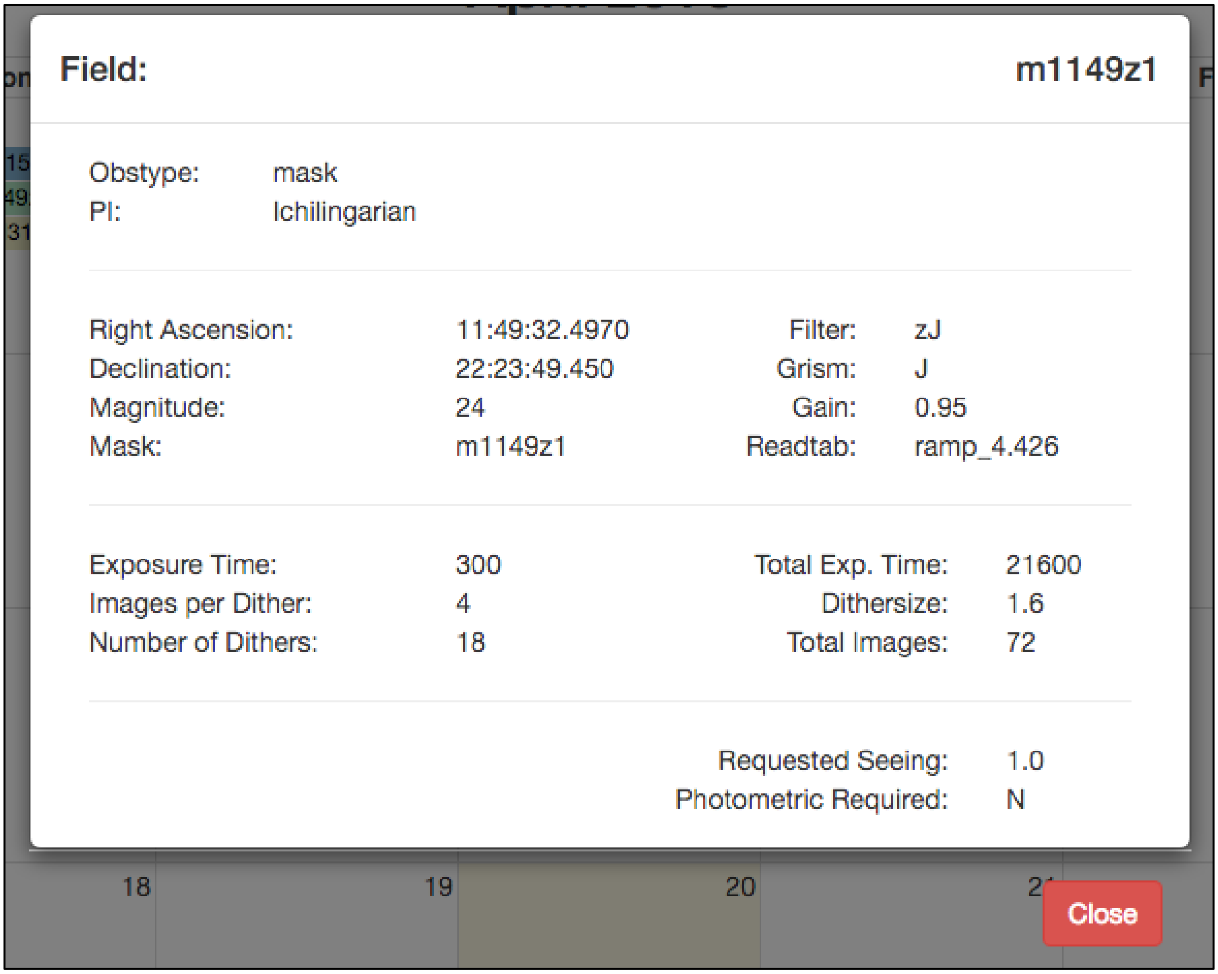


Figure 10. Details from one field that appears when a user clicks on one of the fields for the night. This structure provides the queue observer all information needed in order to set up and observe the field as specified in the Phase II information.

**f/15 Instrumentation**

There was one adaptive optics (AO) run this quarter, February 16-28. It consisted of 13 total nights: one M&E night and 12 science nights. During the 13 nights, no major issues were encountered with the AO system, and good science and engineering data was collected on all nights excluding closures due to weather conditions. The wavefront sensor (WFS) camera fiber converter card was installed and used throughout the run with the exception of the final night where the old SCSI card was used to allow for acquisition of very faint targets.

Several software improvements to the system were tested and validated during the run. The WFS camera fiber converter card proved much more reliable than the old SCSI card, and helped greatly in improving the overall system efficiency. In addition, when problems did occur, it was much simpler and faster to recover from the failure and resume operations. WFS camera background subtraction was also tested and proved necessary for using the fiber converter card. Some testing was performed on the PID controller and "seeing limited mode." However, these tests proved inconclusive due to electrical noise issues.

An intermittent 60 Hz noise issue has been causing problems with the WFS camera slope calculations, resulting in significant degradation of the image correction. This issue will be investigated further on M&E nights during the next AO run. If the 60 Hz noise issue is resolved, further testing can resume on the PID controller and the "seeing limited mode."

K. Powell worked with P. Hinz and others from Steward Observatory's Center for Astronomical Adaptive Optics (CAAO) on a proposal for improvements to the AO system. It was submitted at the end of February to the National Science Foundation's MSIP program. The awards will be announced in late May or early June.

## Topboxes and Wavefront Sensors (WFS)

### f/5 WFS

During the December 2015 MMIRS run, WFS camera 2 was inoperable and the correction using WFS camera 1 was found to be detrimental. During the March MMIRS run we tested corrections using both WFS camera 1 and camera 2, and revised software to work robustly for each camera. The following are key changes to the code that allowed the successful use of both cameras:

- The WFS software was made camera-aware (previously, only the spot-finding algorithm knew which of the two cameras was in operation). This allows the inclusion of separate focus offsets for each of the two WFS cameras. The focus offset was fine-tuned by first finding a robust correction with camera 2 (using a well-known focus offset) and then determining the focus offset needed in camera 1 to achieve the same focus value.
- When "in continuous mode" was enabled, focus corrections greater than 30 microns were ignored. This led to problems when the telescope was far out of focus or when rapid temperature changes resulted in large focus swings. These focus variations are now allowed at a significantly small gain (as with all continuous WFS operations) such that we don't expect to see sudden large swings in the focus value.
- Care was given to refining the WFS camera 1 reference template, including empirical placement of the hole in the primary mirror.

There were a few instances during the March run where bad corrections were determined and applied, leading to poor image quality. The new image quality was sufficiently poor so that the WFS code began diverging when trying to correct the system. For now, the gain in the continuous system has been reduced to make sudden changes less impactful to the full system. Since the WFS images are read every 30 seconds, if it's a real change we can converge quickly to the new minimum.

While not yet tested, we have developed a continuous WFS interface for operations with the f/5 WFS camera, primarily for MAESTRO. This GUI uses the same interface as MMIRS, so operation will be obvious for operators. Currently, this GUI does not appear when standard WFS is started for MAESTRO. To start the software, operators will need to start /mmt/shwfs/maestro_gui from a terminal.

One major shortcoming of using the existing system for continuous WFS with the f/5 WFS camera is that selected stars do not routinely "land" on the WFS sweet spot. As the on-axis star needs to remain fixed, the position of the WFS star cannot be tweaked with the hexapod or mount, as doing so would move the target from the instrument slit. There are two possible solutions: understanding why our calculation to determine the position of the off-axis star is not exact, or write a script that will perform a "nudge" for the WFS to get it to the correct location (while remembering that the WFS camera moves in polar coordinates. We might also need to determine if the process used to center the target in the slit is using the best offset system (alt/az, ra/dec, or instrument offsets).

## Facilities

### Main Enclosure

Work was mostly completed on covering the existing roof with low-emissivity standing seam panels and heating panels. Safety hooks will be added later in the spring.

### General Infrastructure

Work continued on replacing the pavement on the steepest portion of the road between the summit dorm and the MMTO, as well as the addition of a new guard rail system.

Excavation for a new in-ground lift at the telescope continued during this reporting period.

*Ops* and *ops2* computers were moved to their permanent location in the communications room in the IRF. The computers were installed in steel racks mounted to the ceiling. An appropriate-sized UPS was also ordered and installed.

## Computers and Information Technology

### Computers and Storage

*Pixel* (the observer computer) was updated to OS X 10.11 El Capitan. There were initial issues with existing libraries in protected folders (such as IRAF), but several symbolic links later it is operating robustly. One exception is that DS9 takes an extended period of time to open immediately after resetting the mmtobs account on *pixel*, but all subsequent instances open normally.

During the upgrade, it was noticed that the time machine drive used for *pixel* had become unresponsive. It was replaced, and the regularly scheduled time machine backup frame was restarted. The backup, restore, and reset scripts for the mmtobs account were upgraded to ensure that all products needed for each instrument are preserved in a robust way, while also not exposed when not needed (*i.e.*, SSH keys).

**Network**

The software group performed the usual monthly backups and reboots of the Linux servers. The yearly offload of historical data from /*mmt* was also performed, transferring the data to two external USB drives.

The Fedora Linux machines were updated to release 23.

The new "mmto.org" SSL certificate, which is used for secure web authentication, was installed.

Issues with the mmt-ntp network time protocol (NTP) server at the summit were resolved with a firmware upgrade from the manufacturer. A separate issue with NTP time was corrected on *ops*.

The "alx ethernet driver" problem persists with upgrades for *chisel* and *pipewrench* (telescope operator computer and backup/AO operator computer). Linux kernel drivers for this particular ethernet device are not being supported in new Fedora releases. It is preventing these computers from being updated to the current Linux kernel.

The software group has worked with University Information Technology Services (UITS) on "broken pipe" errors with SSH connections from off-campus. These errors affected both MMT staff working off-site as well as astronomers doing remote observing. The problem was apparently resolved by UITS by early March.

The operating system on *pipewrench* was re-installed after the failing hard drive was replaced.

A minor problem with LDAP, used for user authentication, was fixed on *chisel* and *pipewrench*.

A new UPS was installed in the communications room at the summit. Several computers, including those related to the fire alarm system, were moved to the new UPS.

The loft_neslab_auto miniserver was modified according to the new specifications for the control algorithm. A new annunciator check on the loft_neslab setpoint was implemented.

Occasional flashing on telstat displays persists. This may be related to high temperatures in the telstat display computers. Work continues to resolve these monitor issues.

Monitoring of MMIRS rack temperatures was started. Emails will be sent to appropriate staff if abnormally high temperatures are measured.

Preliminary work was done on evaluating primary mirror actuator data taken over the past few years. Systematic shifts and changes in noise levels are seen. These shifts may be related to changes in calibration coefficients, power supplies, or other factors. Work continues in this area.

### Hardware/Software Interfaces

The loose connection discovered in the operators' paddle (see p. 3) led to a discussion of decreasing its size as many items on the paddle are no longer used. Plans are to redesign the unit in the near future.

## Weather and Environmental Monitoring

### Seeing

As discussed in previous quarterly reports, the MMIRS instrument, a wide-field near-IR imager and multi-object spectrograph, generates WFS-related seeing values much more quickly than other f/5 or f/9 instruments. This instrument was on the telescope January 1-3 and March 17-28. Of the 8397 total WFS data samples for the period of January 1 to April 1, 5349 are from MMIRS. There are 2521 f/5 seeing values that are not from MMIRS (*e.g.,* Hecto) and 527 seeing measurements from f/9 instruments.

Figures 11 and 12 present seeing values, corrected to zenith, at the MMTO during this reporting period. These values are derived from measurements made by the f/5 (MMIRS and non-MMIRS) and f/9 WFSs. Figure 11 presents the seeing values as a histogram with 0.1 arcsec bins while Figure 12 presents the same data as a time-series chart. f/5 WFS values are divided into MMIRS and non-MMIRS categories. In Figure 11, f/5 MMIRS seeing data are shown in blue, f/5 non-MMIRS data in green, f/9 data in red, and the combination of all three WFS values is in cyan. In Figure 12, seeing measurements for the f/5 are similarly shown as blue (MMIRS) and green (non-MMIRS) diamonds while f/9 WFS seeing measurements are represented by red squares.

The median f/5 seeing value for MMIRS data is 0.95 arcsec. This represents an improvement from the 1.07 arcsec in the October-December 2015 quarter. However, data from late 2015 were obtained during only a few days of observation. The median non-MMIRS f/5 seeing is 0.83 arcsec while the median f/9 seeing value is 0.93 arcsec. This latter value represents a relatively large decrease in seeing quality from the 0.76 arcsec value of the October-December 2015 quarter. The combined median seeing for all data WFS systems is 0.92 arcsec. As previously stated, the combined data set is biased towards nights of MMIRS observing.

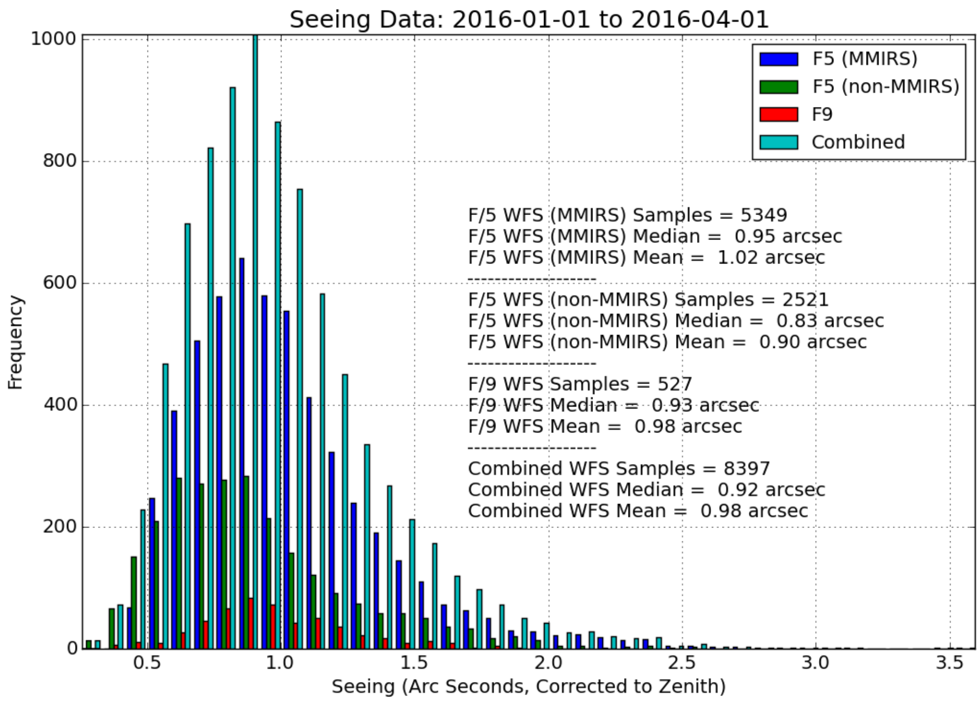


Figure 11. Histogram (with 0.1 arcsec bins) of derived seeing values for the f/5 (MMIRS and non-MMIRS) and f/9 WFSs from January through March 2016. Seeing values are corrected to zenith. The median f/5 MMIRS seeing is 0.95 arcsec and f/5 non-MMIRS seeing is 0.83 arcsec while the median f/9 seeing is 0.93 arcsec. A combined median seeing value of 0.92 arcsec is found for the total 8397 WFS measurements made during this period.

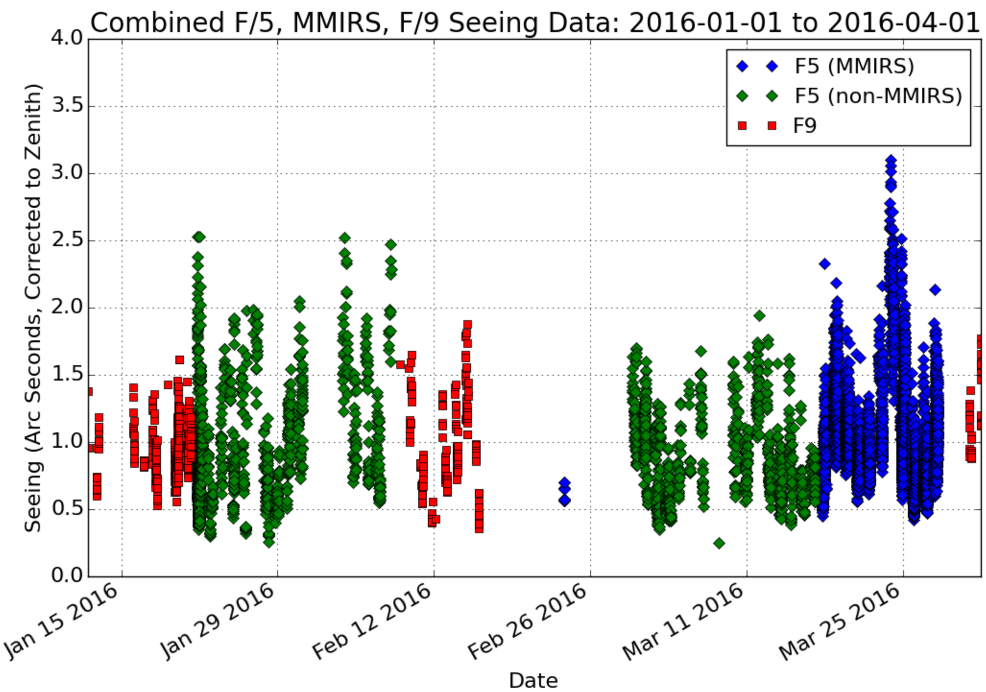


Figure 12. Derived seeing for the f/5 (MMIRS and non-MMIRS) and f/9 WFSs from January through March 2016. Seeing values are corrected to zenith. f/5 seeing values are shown in blue (MMIRS) and green (non-MMIRS) while f/9 values are in red. Data from MMIRS are typically sampled more frequently than for other instruments.

## User Support

### Remote Observing

This quarter a total of 18.35 nights of remote observing were supported by the MMTO. CfA used 5.5 nights, and 12.85 nights were used by the UA. The software group began to experience intermittent loss of connectivity to the mountain - repeated "broken pipes" during SSH sessions, which were reported to UITS in January by S. Schaller. Remote observers were warned that broken pipes would not interrupt data acquisition in progress, but were likely to result in inefficient observing. Mac users' sessions automatically reconnected immediately, but in that time to reconnect, users had no way to start new exposures. Some remote observers reported broken pipes, while others had no issues. By the beginning of March this problem appeared to have been resolved by UITS.

### Data Archive

As part of the ongoing archiving of the Red and Blue Channel data, a large amount of data has been amassed on the typical setups used by longslit observers at the MMTO. A simple python script was written that reads the header of each image in our archive and then stores the header information for further analysis. Here, some of the statistics from this archive are described. Note that this is the distribution of object frames, thus there can be some bias if programs do many, many exposures compared to longer exposures. However, over the 3-year baseline present in the archive, this effect is expected to be small. Some individual plots will have their own biases or caveats, which are noted in the text describing the following figures.

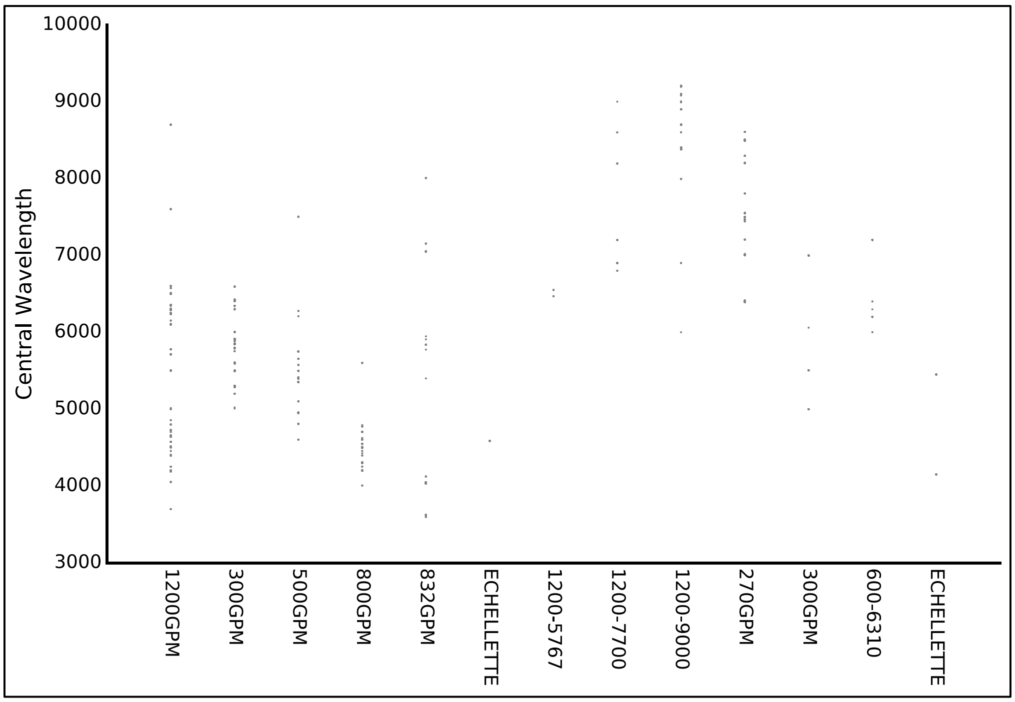


Figure 13. The range of Blue and Red Channel setups is shown.

Figure 13 shows the range of setups used for both Red and Blue Channel. Orders are not separated in this plot. For example, the tail of very red central wavelengths with the 832 gpm Blue Channel grating are in 1st order, while the blue bulk of images uses the standard 2nd order.

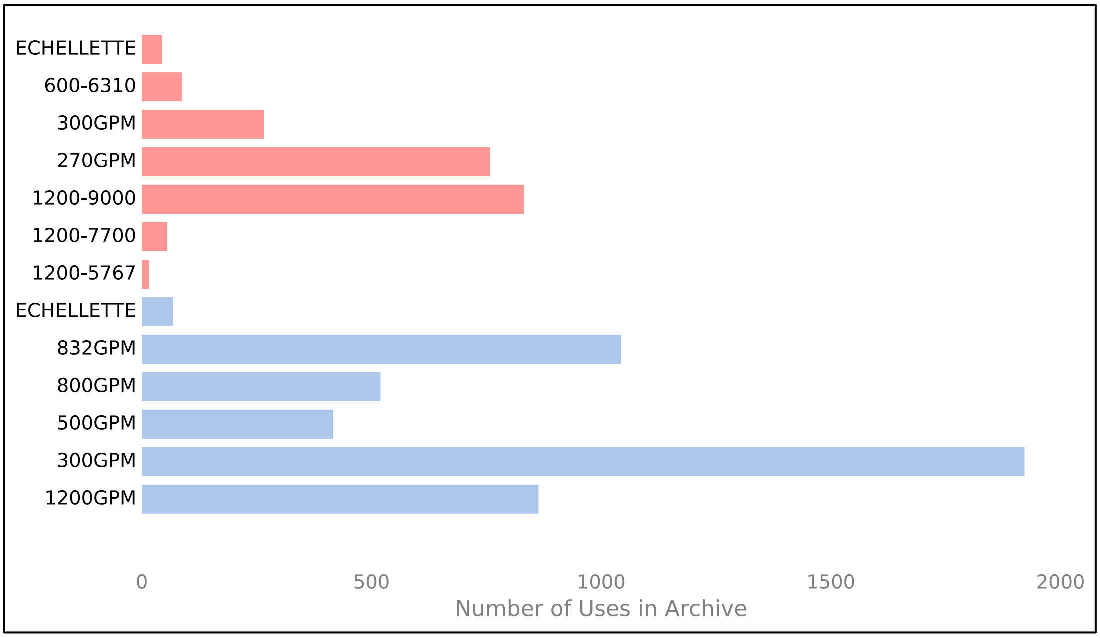


Figure 14. The distribution of grating usage for Red and Blue Channel.

The distribution of grating usage for Red and Blue Channel is shown in Figure 14. The relative heights of these bars can be deceiving, as one usage is equal to one image rather than one night. Only object images are included. Observers taking a wealth of calibration frames, or calibration frames taken during poor weather that prevents science frames, does not impact these counts.

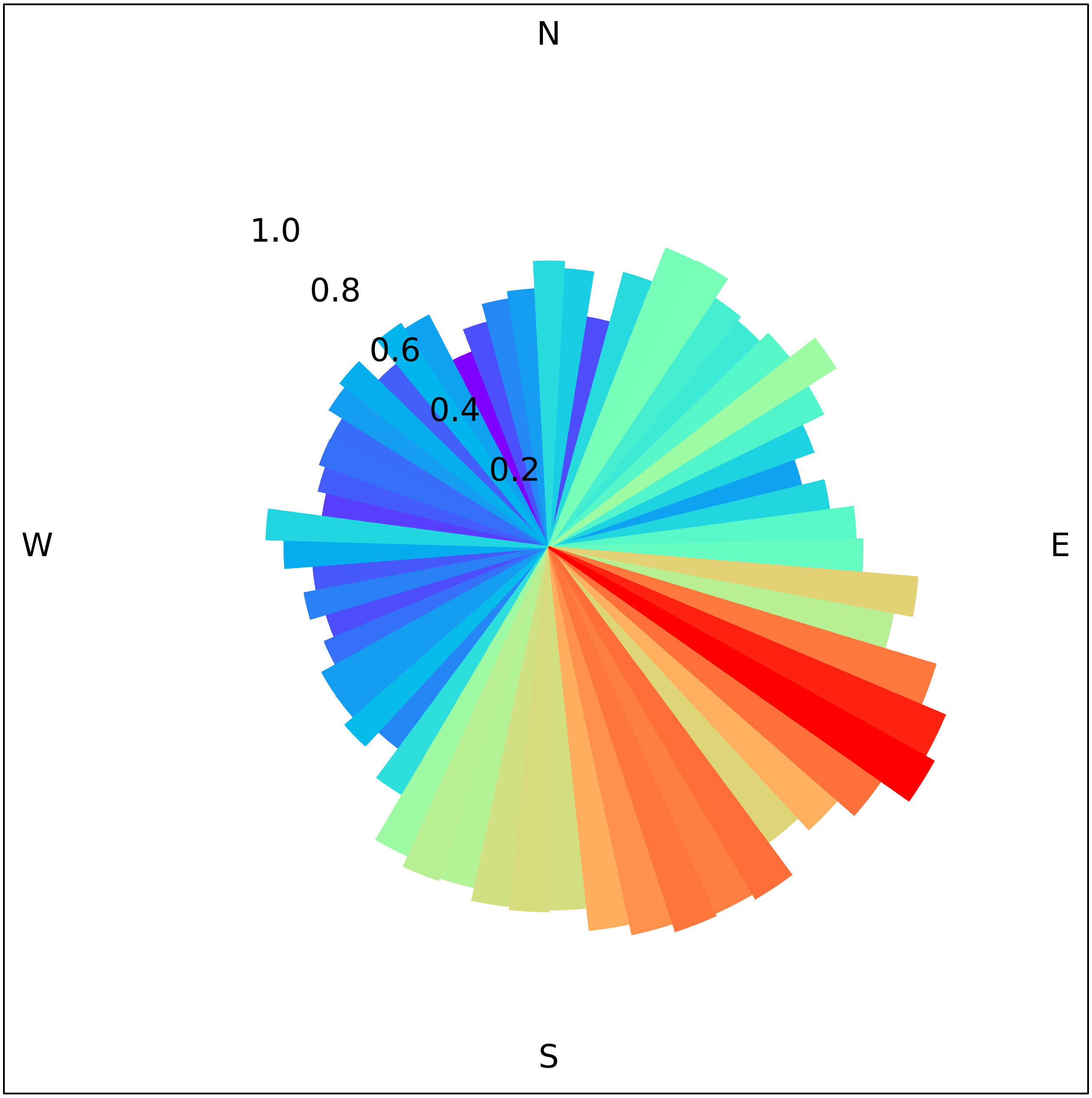


Figure 15. Two dimensional distribution of seeing, parameterized by wind direction.

Care must be taken in reading too much into the plot shown in Figure 15, as the worst seeing prevents WFS images from being completed, which would result in no seeing information written to the headers. Of course, in the worst conditions where seeing is extremely poor, no images will be taken, so this wind rose will be biased toward lower seeing than average. Regardless, the well-known trend that wind direction plays a significant role in the average seeing at the MMT is clearly reflected in this figure.

## Documentation

Nothing to report.

## Public Relations and Outreach

### Visitors and Tours

2/9/16 – G. Williams led a tour of the MMTO for D. Friend (founder of the company, Carbonite) and seven of his guests. B. Jannuzi, director of Steward Observatory, and four others also accompanied the group.

2/10/16 – A film crew visited the MMTO and filmed material in preparation for Prof. Roger Angel's induction into the Inventor's Hall of Fame.

3/9/16 – Several guests attending a Space Situational Awareness meeting, along with colleagues from the Univ. of Arizona led by M. Hart, were given a tour of the MMTO by G. Williams. The guests were from NASA, IARPA, and Air Force Space Command.

3/12/16 – D. McCarthy led a tour of the MMTO with prospective Steward Observatory graduate students.

3/23/16 – An appreciation dinner for FLWO volunteers was held on March 23. The volunteers were given tours of the Ridge telescopes and of the MMTO (by G. Williams) with dinner following at the Ridge dorm.

3/25-26/16 – A professor and four graduate students from Cardiff University in Wales visited the MMTO to watch some nighttime operations and were also given a tour by E. Falco.

### Public Presentations

J. Hinz organized the Smithsonian Lectures on Astronomy series held in Green Valley, AZ. Attendance for the five lectures held January through March, was above previous years with top figures near 350-400 people. Lecturers were recruited from all three Arizona universities.

J. Hinz gave a presentation on February 17 to the Whipple Observatory volunteers at the Visitors Center as a refresher before tours resume in May.

MMTO staff supported an informational booth at the annual Tucson Festival of Books held March 12-13. An updated version of the virtual tour of the MMT Observatory was created by D. Porter. Hundreds of visitors to the Festival used the Oculus virtual reality headgear to make the virtual tour. Informational handouts about the MMTO were also given out.

# Appendix I - Publications

## MMT Related Scientific Publications

*(An online publication list can be found in the MMTO ADS library at [http://www.mmto.org/node/244](http://www.mmto.org/node/244))*

16-01 An HST Survey of the Highest-velocity Ejecta in Cassiopeia A
R. Fesen and D. Milisavljevic
*ApJ*, **818**, 17

16-02 Evidence that Hydra I is a Tidally Disrupting Milky Way Dwarf Galaxy
J.R. Hargis, B. Kimmig, B. Willman, et al.
*ApJ*, **818**, 39

16-03 Probing the Outskirts of the Early-Stage Galaxy Cluster Merger A1750
E. Bulbul, S.W. Randall, M. Bayliss, et al.
*ApJ*, **818**,131

16-04 Reverberation Mapping with Intermediate-band Photometry: Detection of Broad-line Hα Time Lags for Quasars at $0.2 < z < 0.4$
L. Jiang, Y. Shen, I.D. McGreer, et al.
*ApJ*, **818**, 137

16-05 The ELM Survey. VII. Orbital Properties of Low-Mass White Dwarf Binaries
W.R. Brown, A. Gianninas, M. Kilic, et al.
*ApJ*, **818**, 155

16-06 HectoMAP and Horizon Run 4: Dense Structures and Voids in the Real and Simulated Universe
H.S. Hwang, M.J. Geller, C. Park, et al.
*ApJ*, **818**, 173

16-07 The First Transition Wolf-Rayet WN/C Star in M31
M.M. Shara, J. Mikolajewska, N. Caldwell, et al.
*MNRAS*, **455**, 3453

16-08 The Persistent Eruption of UGC 2773-OT: Finally, a Decade-long Extragalactic Eta Carinae Analogue
N. Smith, J.E. Andrews, J.C. Mauerhan, et al.
*MNRAS*, **455**, 3546

16-09 Searching for Cool Dust in the Mid-to-Far Infrared: The Mass-loss Histories of the Hypergiants μ Cep, VY CMa, IRC+10420, and ρ Cas
D. Shenoy, R.M. Humphreys, T.J. Jones, et al.
*AJ*, **151**, 51

16-10 A Constraint on Quasar Clustering at $z = 5$ from a Binary Quasar
I.D. McGreer, S. Eftekharzadeh, A.D. Myers, et al.
*AJ*, **151**, 61

16-11 A Survey of Luminous High-redshift Quasars with SDSS and WISE. I. Target Selection and Optical Spectroscopy
F. Weige, X.-B. Wu, X. Fan, et al.
*ApJ*, **819**, 24

16-12 HeCS-SZ: The Hectospec Survey of Sunyaev-Zeldovich-selected Clusters
K.J. Rines, M.J. Geller, A. Diaferio, et al.
*ApJ*, **819**, 63

16-13 The Metallicity Evolution of Blue Compact Dwarf Galaxies from the Intermediate Redshift to the Local Universe
J. Lian, N. Hu, G. Fang, et al.
*ApJ*, **819**, 73

16-14 Hot Dust Obscured Galaxies with Excess Blue Light: Dual AGN or Single AGN Under Extreme Conditions?
R.J. Assef, D.J. Walton, M. Brightman, et al.
*ApJ*, **819**, 111

**MMT Technical Memoranda / Reports**

None

**Non-MMT Related Staff Publications**

Globular Cluster Populations: Results Including S4G Late-Type Galaxies
Zaritsky, D., McCabe, K., Aravena, M., et al. (J. Hinz)
*ApJ*, **818**, 99

## Appendix II - Service Request (SR) and Response Summary: January - March, 2016

The MMT Service Request (SR) system is an online tool to track ongoing issues that arise primarily during telescope operations, although the system can be used throughout the day and night by the entire staff. Once an SR has been created, staff members create responses to address and eventually close the SR. These SRs and associated responses are logged into a relational database for later reference.

Figure 16 presents the distribution of SR responses by priority during the period of January through March 2016. As seen in the figure, the highest percentage (55%) of responses are "Important" priority, followed by 18% "Information Only" and 15% "Near-Critical." In addition, 6% are "Critical" and 6% "Low" priority.

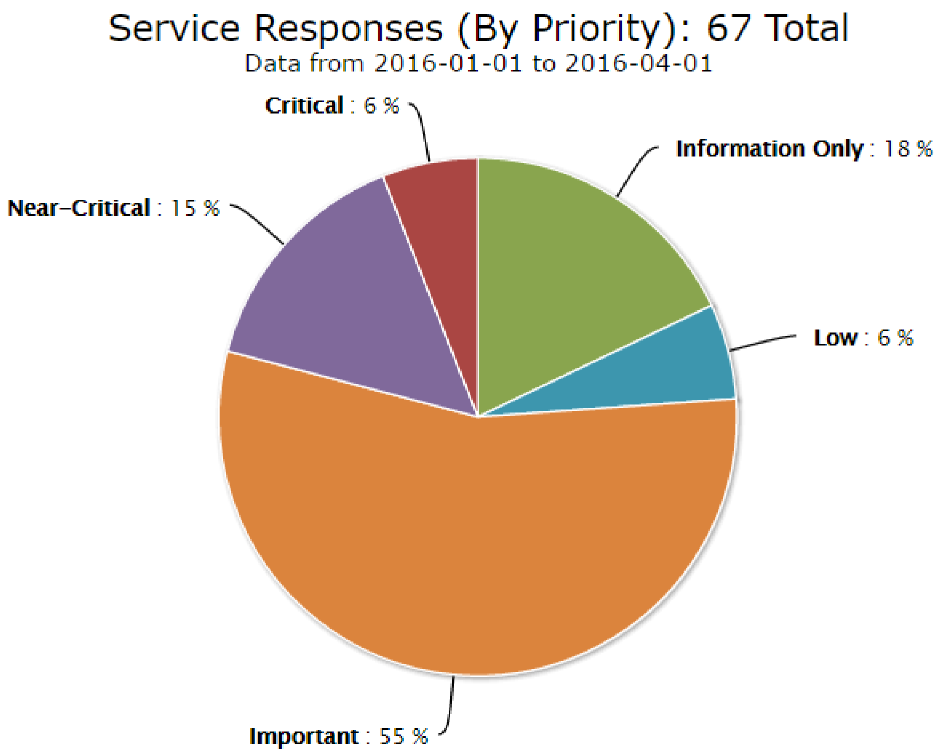


Figure 16. Service Request responses by priority during January through March 2016. 55% are "Important" responses, 18% are "Information Only," 15% "Near-Critical," 6% "Critical," and 6% "Low."

"Critical" SRs address issues that are preventing telescope operation, while "Near-Critical" SRs relate to concerns that pose an imminent threat to continued telescope operation. There were a total of 67 SRs during this three-month period, down from 71 SRs during the previous three-month reporting period.

Figure 17 presents the same 67 SR responses grouped by category. These categories are further divided into subcategories for more detailed tracking of issues. The majority of the responses from January through March were related to the "Telescope," "Computers/Network," and "Building" categories with 16, 11, and 9 responses, respectively. Responses also occurred in the "Cell," "Control Room," "Electronics," "Software," "Support Building," "Thermal System," and "Weather Systems" categories.

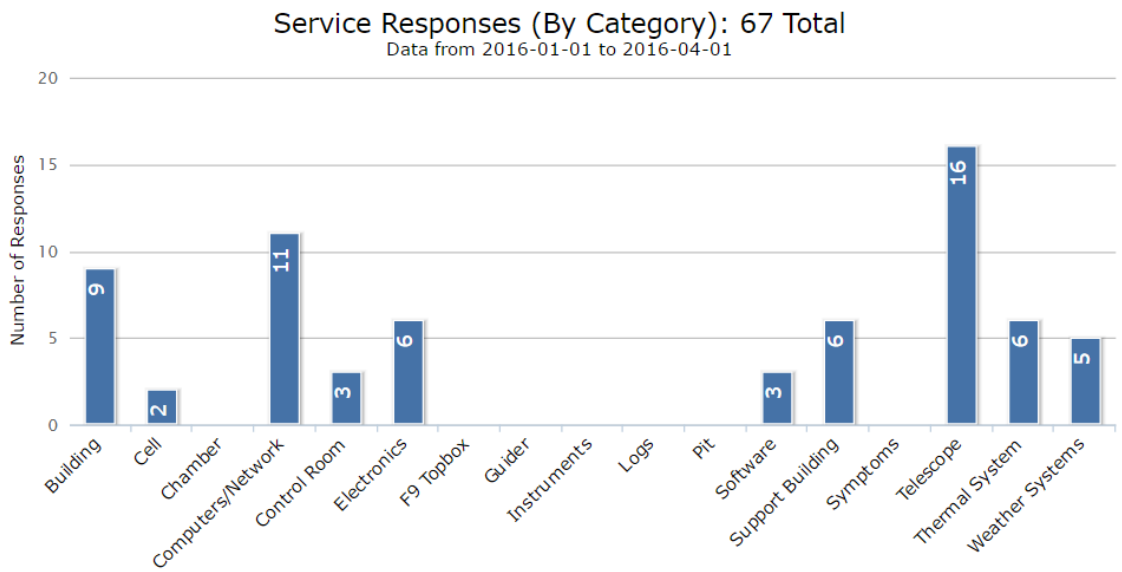


Figure 17. Service Request responses by category during January through March 2016. The majority of responses were within the "Telescope," "Computers/Network," and "Building" categories.

## Appendix III - Observing Statistics

The MMTO maintains a database containing relevant information pertaining to the operation of the telescope, facility instruments, and the weather. Details are given in the June 1985 monthly summary. The data attached to the back of this report are taken from that database.

## Use of MMT Scientific Observing Time

### January 2016

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | *Lost to Instrument | **Lost to Telescope | ***Lost to Gen'l Facility | ****Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 17.00 | 201.10 | 127.00 | 0.00 | 0.00 | 1.00 | 0.00 | 128.00 |
| PI Instr | 13.00 | 152.20 | 10.55 | 0.00 | 0.00 | 0.00 | 0.00 | 10.55 |
| Engr | 1.00 | 11.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **31.00** | **365.00** | **137.55** | **0.00** | **0.00** | **1.00** | **0.00** | **138.55** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 96.8 |
| Percentage of time scheduled for engineering | 3.2 |
| Percentage of time scheduled for sec/instr change | 0.0 |
| Percentage of time lost to weather | 37.7 |
| Percentage of time lost to instrument | 0.0 |
| Percentage of time lost to telescope | 0.0 |
| Percentage of time lost to general facility | 0.3 |
| Percentage of time lost to environment (non-weather) | 0.0 |
| Percentage of time lost | 38.0 |

*** Breakdown of hours lost to facility
1.00 Hacksaw server crash

### February 2016

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | *Lost to Instrument | **Lost to Telescope | ***Lost to Gen'l Facility | ****Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 8.00 | 89.80 | 3.25 | 0.00 | 0.75 | 0.00 | 0.00 | 4.00 |
| PI Instr | 19.00 | 210.90 | 75.81 | 4.00 | 5.00 | 0.08 | 0.00 | 84.89 |
| Engr | 2.00 | 22.20 | 11.10 | 0.00 | 0.00 | 0.00 | 0.00 | 11.10 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **29.00** | **322.90** | **90.16** | **4.00** | **5.75** | **0.08** | **0.00** | **99.99** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 93.1 |
| Percentage of time scheduled for engineering | 6.9 |
| Percentage of time scheduled for sec/instr change | 0.0 |
| Percentage of time lost to weather | 27.9 |
| Percentage of time lost to instrument | 1.2 |
| Percentage of time lost to telescope | 1.8 |
| Percentage of time lost to general facility | 0.0 |
| Percentage of time lost to environment (non-weather) | 0.0 |
| Percentage of time lost | 31.0 |

* Breakdown of hours lost to instrument
0.50 Hecto could not pull guide stars in
2.75 Aries first night set up
0.75 Image quality problems with Aries

** Breakdown of hours lost to telescope
0.25 Mount crate had to be rebooted
0.50 MMT-NTP providing old time to mount
0.50 AO computer problem
4.50 26V rack failure

*** Breakdown of hours lost to facility
0.08 Power outage

### Year to Date February 2016

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | Lost to Instrument | Lost to Telescope | Lost to Gen'l Facility | Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 25.00 | 290.90 | 130.25 | 0.00 | 0.75 | 1.00 | 0.00 | 132.00 |
| PI Instr | 32.00 | 363.10 | 86.36 | 4.00 | 5.00 | 0.08 | 0.00 | 95.44 |
| Engr | 3.00 | 33.90 | 11.10 | 0.00 | 0.00 | 0.00 | 0.00 | 11.10 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **60.00** | **687.90** | **227.71** | **4.00** | **5.75** | **1.08** | **0.00** | **238.54** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 95.1 |
| Percentage of time scheduled for engineering | 4.9 |
| Percentage of time scheduled for sec/instr change | 0.0 |
| Percentage of time lost to weather | 33.1 |
| Percentage of time lost to instrument | 0.6 |
| Percentage of time lost to telescope | 0.8 |
| Percentage of time lost to general facility | 0.2 |
| Percentage of time lost to environment (non-weather) | 0.0 |
| Percentage of time lost | 34.7 |

**March 2016**

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | *Lost to Instrument | **Lost to Telescope | ***Lost to Gen'l Facility | ****Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 2.00 | 19.60 | 14.63 | 0.00 | 1.16 | 0.00 | 0.00 | 15.79 |
| PI Instr | 28.00 | 288.70 | 53.78 | 2.00 | 2.20 | 0.25 | 0.00 | 58.23 |
| Engr | 1.00 | 10.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **31.00** | **318.50** | **68.41** | **2.00** | **3.36** | **0.25** | **0.00** | **74.02** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 96.8 |
| Percentage of time scheduled for engineering | 3.2 |
| Percentage of time scheduled for secondary change | 0.0 |
| Percentage of time lost to weather | 21.5 |
| Percentage of time lost to instrument | 0.6 |
| Percentage of time lost to telescope | 1.1 |
| Percentage of time lost to general facility | 0.1 |
| Percentage of time lost to environment | 0.0 |
| Percentage of time lost | 23.2 |

* Breakdown of hours lost to instrument

0.25 Hecto guider not making corrections
1.00 MMIRS software issues
0.75 MMIRS cam2 and Dekker wheel not moving

** Breakdown of hours lost to telescope

0.50 M1 panic
1.70 Building LVDT issues & mirror cover failure
1.16 Rotator problems

*** Breakdown of hours lost to facility

0.25 SE building wheel scraping

**Year to Date March 2016**

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | Lost to Instrument | Lost to Telescope | Lost to Gen'l Facility | Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 27.00 | 310.50 | 144.88 | 0.00 | 1.91 | 1.00 | 0.00 | 147.79 |
| PI Instr | 60.00 | 651.80 | 140.14 | 6.00 | 7.20 | 0.33 | 0.00 | 153.67 |
| Engr | 4.00 | 44.10 | 11.10 | 0.00 | 0.00 | 0.00 | 0.00 | 11.10 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **91.00** | **1006.40** | **296.12** | **6.00** | **9.11** | **1.33** | **0.00** | **312.56** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 95.6 |
| Percentage of time scheduled for engineering | 4.4 |
| Percentage of time scheduled for secondary change | 0.0 |
| Percentage of time lost to weather | 29.4 |
| Percentage of time lost to instrument | 0.6 |
| Percentage of time lost to telescope | 0.9 |
| Percentage of time lost to general facility | 0.1 |
| Percentage of time lost to environment | 0.0 |
| Percentage of time lost | 31.1 |