MODERNIZATION OF THE MOUNT WILSON 60-INCH TELESCOPE

NASA CONTRACT NSR 09-140-001

FINAL REPORT

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I. Introduction

This is the final report on the contract to modernize the 60-inch telescope on Mount Wilson. We shall first review the present status of the telescope including work performed since the last quarterly report, and then give a summary of all results of the work achieved under the contract.

Most of the main modifications of the telescope itself, including rewiring and the installation of the drives and other subassemblies that had been built in Pasadena, were carried out during the summer of 1969 and the telescope was returned to regular operation in mid-August 1969. Some additional modifications continued through December. These included, primarily, the final installation of digital coordinate readouts for right ascension and declination, which are now displayed at the control console; overhauling of the main declination axis bearings resulting in a substantial reduction in operating torque; realignment of the telescope polar axis with respect to the celestial pole; and installation of the new coudé spectrograph. Some difficulties were anticipated in getting the 4000 pound spectrograph into the confined space of the spectrograph room, but this was finally accomplished without mishap. All components of the spectrograph have been attached and are in working order. The spectrograph is now undergoing final alignment and testing.

On the telescope itself, the only remaining task is the completion of a gravity-preload for the declination axis, which was partially designed earlier. It is being completed with funds of the Carnegie Institution.

A computer-controlled data-acquisition system for use with the telescope was about 50 percent completed (including the tracking oscillator and readouts now in service). Additional funds in the amount of about $70,000, of which $60,000 has been requested from NASA, will be required to complete and install this data system. A copy of the supplementary proposal is attached (Appendix).

The telescope has been in continuous use since the completion of the major renovation in August of last year. In a representative five month period (to February 22, 1970), the scheduled observations were distributed as follows:

Observations of Planets, Asteroids, and the Moon (largely in the infrared)	29%
Stellar infrared studies ($\lambda > 1.5\mu$)	26%
Stellar photometry ($\lambda < 1.5\mu$)	11%
Studies of gaseous nebulae	20%
MK spectral classification	8%
Other (including telescope testing)	6%
	100%

Carnegie Institution and California Institute of Technology staff	33%
Guest investigators from other institutions	26%
Graduate students (Caltech)	41%
	100%

In the following Section the major aspects of the modernization program are reviewed. An evaluation of the results of the program and some recommendations regarding further needs are given in Section III.

II. Resumé of Work Accomplished under NSR 09-140-001 and Related Modifications

1. Mezzanine Floor

In order to provide a convenient accomodation for other improvements to the telescope facility, an early task in the modernization program was completion of a mezzanine-level floor, midway between ground level and the observing floor; no working areas originally existed at this level. The mezzanine level incorporates (1) a new coudé observing room, (2) an air-conditioned data-acquisition room to house the computer, printers, and other electronics, and (3) a "clockroom" containing the base of the telescope with its driving machinery and maintenance equipment. These building modifications were funded primarily by the Carnegie Institution.

2. Polar Axis

The new polar axis driving system utilizes the original main polar axle, fork, bearings, preload, 1440-tooth worm gear, and worm, which are of good design and in sound condition. The old gravity driven mechanical governor that originally drove the telescope was replaced by a solid-state digital clock, electric drive, and worm shaft encoder. These are identical to the drive system of the new Palomar 60-inch photometric telescope.

In the new driving system, fast-setting or slewing as well as tracking are accomplished through the main worm gear. The latter is now permanently clutched to the polar axis shaft. By controlled acceleration, deceleration, and braking the fast-setting loads are made to fall within very safe limits. The old fast-setting components have been removed, thus effecting a substantial reduction in frictional load.

The tracking oscillator, designed and tested for future computer control, can be set manually as well for drift rates from -5000 to +5000 seconds of arc per hour in steps of 1 second of arc per hour. Slow setting and guiding of the telescope in right ascension are controlled by a stepping motor. The drive and related electronics have given trouble-free service since installation.

3. Declination Axis

The original declination ball bearing, defining, and radial counterweight system, although of sound design, required partial disassembly and maintenance to bring the frictional torques down to within acceptable allowances for the new drives. The overhauled bearing torques are now as low as can be expected for bearings of this design, a factor of 4-10 lower than they were prior to renovation.

The old declination slewing and guiding motors, gears, and tangent arm were removed. A new 60-inch diameter worm gear and drive assembly (also identical to the Palomar 60-inch) was installed at the east fork.

The drive includes two stepping motors, one that applies the guide/set slow motion and another that provides for an adjustable north or south "rate" to compensate for atmospheric refraction, or planetary motion, or for area scanning. The worm shaft encoder readout is displayed, along with that of right-ascension, at the control desk. Both the RA and Dec readouts have been designed and tested for future interfacing to a computer.

Some difficulties have had to be overcome, as a result of the still fairly large declination torque requirements in guiding at large hour angles, which has necessitated the use of a larger guide/set stepping motor than originally planned, and through lack of a declination preload. Until a preload is installed, it is necessary to unbalance the tube in order to take up the declination gear backlash in one direction or the other, clearly an undesirable complication. The completion of a suitable preload system is in progress now under Carnegie Institution funding.

4. Cassegrain - coudé secondary mirror "flip" cage

An existing prime-focus cage (almost never used in the past) was modified so as to provide a quick change support for the Cassegrain and coudé secondaries. This will allow time-sharing and better utilization of nights unsuitable for photometry but adequate for spectroscopic work. About ten minutes are required to convert from one station to the other with this arrangement. The new system provides for a focus encoder, although this feature has not yet been activated. The old Cassegrain and coudé cages have been saved in case of a possible future use for them. Cage changes are still required in order to convert to the Newtonian focus, for which there continues to be a significant although diminishing demand.

5. Telescope control desk and telescope wiring

During the course of the renovations, nearly all the old electrical wiring in the building except that connected with dome rotation and the dome shutter was removed and replaced by new wiring, lights, switches and fuses, and a new main power panel was installed to meet building code requirements. The most extensive wiring comprised the complete power and control system of the telescope itself. All control functions of the telescope, including dome rotation, telescope motions, mirror covers, focussing, tracking rates, coordinate readouts, etc., are now more conveniently centralized at a control desk to the south of the telescope.

Rewiring did not include complete renovation of the dome rotation and shutter systems. For example, the dome is still rotated, at a rather inconveniently slow rate, by dc power generated in the Observatory central power plant and controlled by an obsolete rheostat in the original 60-inch relay panel; installation of a modern solid-state rectifier controller (and possibly a new motor) would allow the dome to be speeded up. Also, the old control relay panel could then be completely disconnected and removed. A similar situation exists in the shutter drive. It will be desirable to carry out these needed improvements in the future.

6. Reactivation of coudé focus

This 60-inch telescope was originally intended by its designer to include a 3-mirror coudé system, and a structurally isolated concrete spectrograph pier and spectrograph chamber (an extension of the dome building) also existed. The new coudé observing room (mezzanine level), together with modifications in the coudé flat driving mechanism, telescope tube, and mirror cover now permit the coudé to be used routinely. The 3-mirror system limits the northern declination to +36° for coudé work; any substantial increase in this limit would have necessitated, in principle, a 7-mirror system which would be quite costly and, indeed, essentially impractical in this telescope.

A new coudé spectrograph was installed incorporating two Schmidt cameras of 3' and 6' focal length and interchangeable 6 x 8 inch turret-mounted gratings yielding the dispersion shown in the accompanying table.

Table 1. Performance of Gratings

BL grating	36" Camera		72" Camera	
	λ (Blaze)	Dispersion	λ (Blaze)	Dispersion
35-53-28-350	7250 Å 3630	18.2 Å/mm 9.1	7350 Å 3680	8.9 Å/mm 4.5
35-53-28-56	12100 Å 6050 4030	18.1 Å/mm 9.1 6.0	12250 Å 6120 4080	8.6 Å/mm 4.3 2.9

(Only the first grating has been purchased thus far.) The spectrograph employs horizontal dispersion as in the 200-inch coudé, partly owing to space restrictions in the chamber, but also because this more easily provides support for radiometers, television, infrared equipment, interferometers, and other specialized accessories on the spectrograph. Unlike the 200-inch coudé the Scmidt corrector is of the once-through type as is necessary for the use of interchangeable gratings. Several other minor departures have been made from the 200-inch design: (a) to improve thermal isolation the slit-viewing microscope is attached to a bulkhead in the concrete chamber wall rather than to the spectrograph; the slit head extends through an aperture in this bulkhead. (b) The retractable corrector plate cell is motor-driven, as are the two mirror covers, to reduce opportunities for damage to the optics. (c) Minor improvements were effected in the slit-guiding assembly and in the mechanism for mounting the plateholders in the two cameras. In the coudé observing room itself, it is possible to direct the beam sideways, east or west, to feed auxiliary apparatus independently of the spectrograph. The room provides ample space for work tables, electronics racks, etc., such as might be needed in connection with specialized experimental work conducted on this telescope.

7. Hoisting equipment

During the course of renovations a new 5-ton hoist and boom was installed in the dome above the observing floor level. The hoist is intended to be used for telescope maintenance and for cage and instrument handling from ground level to observing floor. Smaller hoisting equipment was installed also in the coudé spectrograph chamber to aid in handling the mirrors and other items therein. In the layout of the mezzanine floor, space was allocated for an equipment dumbwaiter; however, construction of the dumbwaiter has been postponed in favor of other improvements with the present contract funds. This and some of the other equipment handling facilities should receive attention as funds permit.

8. Computer controlled data system

Rapid technological developments resulting in the availability of reliable, small-sized programmable digital computers brought about a substantial reassessment of our plans for the 60-inch data acquisition system since 1965, when the proposal for this contract was prepared. The new integrated circuit technology allows, in particular, much more far-reaching goals as regards the scope, speed, and flexibility of data acquisition and recording systems per unit of cost, compared to the older hard-wired systems we originally envisioned. The cost efficiency of the modern computer is so favorable as to make unwise any substantial investment in a less advanced type system.

Since July 1, 1966 approximately $67,000 of funds from this contract have been applied to the design of a computer controlled data system that utilizes integrated circuit technology, and to the purchase of many of its major component parts, including a Raytheon 703 computer and teletype, cathode ray tube display and keyboard, strip printer, tracking oscillator, encoders, and cabinets.

As mentioned previously, all new electronic units now in service (coordinate readouts and displays, variable frequency tracking oscillator) are directly compatible with the planned computer controlled system. Unfortunately, however, slight cost overruns throughout all aspects of the modernization program in the 3-year period have occurred. As a result, additional funding of approximately $70,000, of which $60,000 are being requested from NASA, will be required to complete and install the system. A copy of the proposal submitted to NASA for this support is attached (Appendix).

III. Evaluation

It is desirable to consider separately the factors that affect overall telescope performance in practice, viz. setting accuracy, tracking, guide motions, operational convenience, and safety.

Setting accuracy

The new digital readouts give a reading precision of 1" in declination and $0^{s}.1$ in right ascension. The telescope cannot, of course, be set with this accuracy, but setting errors of 5 - 15 seconds of arc in both coordinates appear to be typical. This is usually sufficient to place an image immediately within the diaphragm of a photometer (provided atmospheric refraction has been taken into account). Since the encoders have negligible backlash they also permit a fairly precise differential offset, and this has been used by some observers. In general, the setting accuracy can be regarded as very satisfactory, representing probably the greatest single step in improving the rate with which observations can be acquired with the telescope.

Tracking

The tracking rate is controlled by a 20 kHz crystal oscillator with an error of less than $1:10^8$ (i.e., negligible error). Some difficulty was anticipated owing to a sizable periodic error that had been known to exist since the beginning and had been presumed to originate in the driving worm. Indeed, many years ago a new worm had been cut in an unsuccessful attempt to eliminate this error. The worm was carefully realigned during the renovation. It now appears that this error must have originated either through worm misalignment or in the old driving clock itself, since with the new tracking drive, using the original worm, it has wholly disappeared.

A digital scaler in the tracking oscillator permits a fine adjustment of the tracking rate in exactly known increments. The performance of this entire system is excellent.

Guiding motions

These are provided by stepping motors. As mentioned previously, it became necessary to use a larger declination stepping motor than originally planned in order to eliminate frictional stalling at large hour angles; it appears that this solution has been successful. Fine declination guiding is still troubled by lack of a preload system, which is being worked on; the present performance is adequate for most purposes. Guiding in right ascension is completely free of backlash and it can be regarded as fully satisfactory.

Operational convenience and safety

This was felt to be an important consideration inasmuch as the original telescope was in many ways awkward to use (especially in the view of less-experienced observers) and difficult or troublesome to service or maintain. The centralization of controls and readouts, the installation of limit switches, and the use of drive machinery and wiring of modern design and quality, are among those improvements that have been most beneficial in this respect.

There do remain some concerns, e.g., rewiring and some mechanical repairs are needed on the rotating dome and shutter, the rigging system for lifting and rotating the Newtonian cage needs improvement, and particularly, the danger of mechanical interference between the telescope and the Newtonian platform requires attention. These matters were not considered in our original contract with NASA.

IV. Photographs

Figure 1. The 60-inch telescope and observing floor, Mount Wilson Observatory, showing new declination drive (east fork) and control consoles (south). Newtonian cage is mounted on the telescope in this photograph. March, 1970.

Figure 2. 60-inch telescope, Mount Wilson Observatory. View of control console and coordinate display unit (left) and digital right ascension tracking oscillator console (right). The oscillator, designed for computer control, will ultimately be relocated in the computer room on the floor below. March, 1970.

Figure 3. 60-inch telescope, Mount Wilson Observatory. Clock room (mezzanine level), showing telescope base and main gear (right), new right ascension drive and coordinate encoder assembly (center,) tracking and stepping motor power console (left rear). March, 1970.