60"

UNITED STATES GOVERNMENT

memorandum

DATE: 2 August 1983

REPLY TO ATTN OF: Frederic H. Chaffe, Jr.

SUBJECT: 60 Inch Realuminizing

TO: 60 Inch Observers

On 23 July 1983, the primary and secondary mirrors were removed from the FLWO 60" telescope and crated for shipment to Liberty Mirror in Brockinridge, PA for realuminizing (for the first time since 1975) and overcoating. We videotaped the mirror removal for archival purposes, and I will send a copy to Cambridge once it is edited and voiced-over.

Don Hogan and Richard Alexander will drive the mirrors to Pennsylvania during the week of August 1, the mirrors will be cleaned and realuminized the week of the 8th and Don and Dick will drive them back to Mt. Hopkins the week of the 15th. They will be reinstalled in the telescope and the telescope will be recollimated the week of the 22nd in time for the end of summer shutdown the night of the 30th.

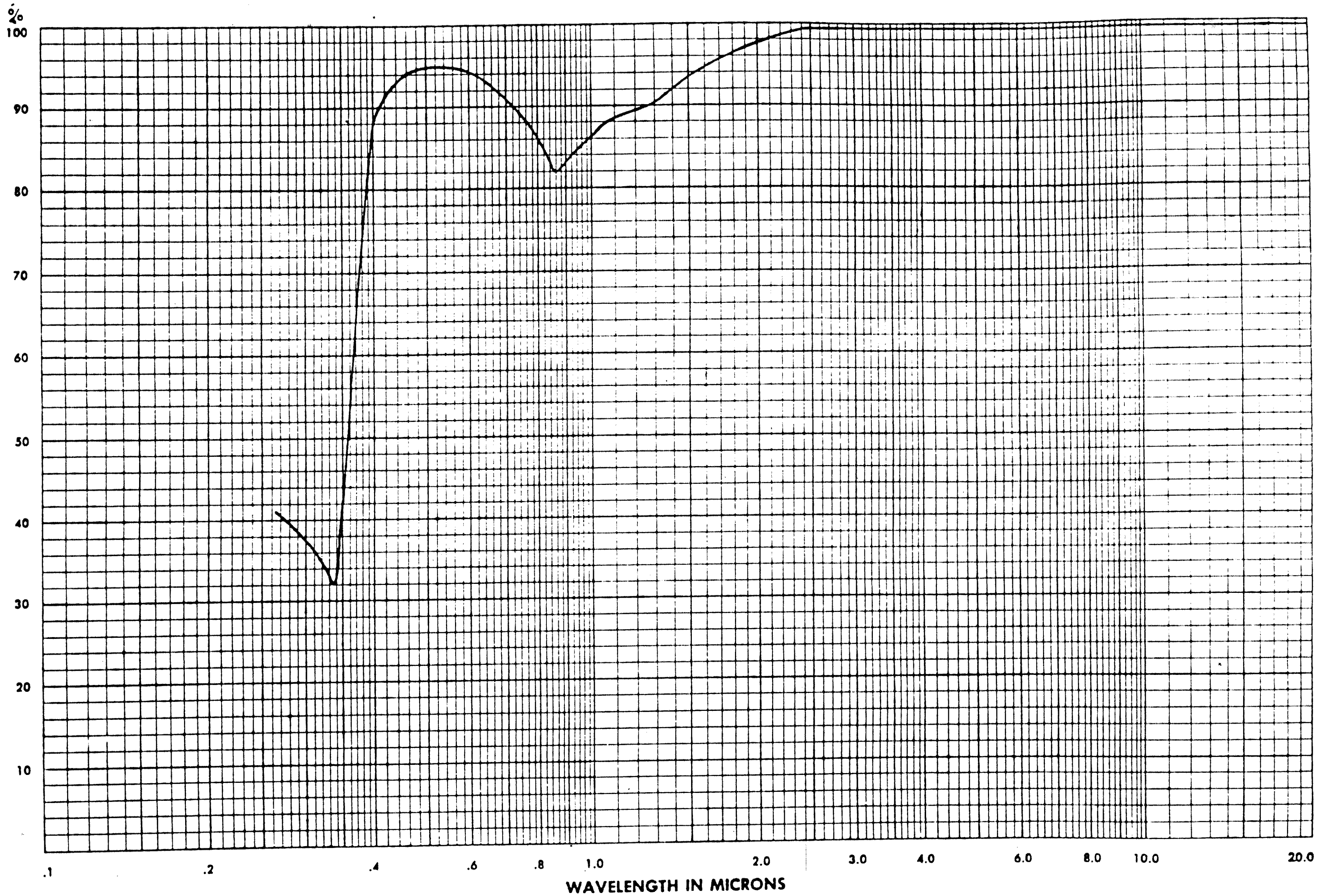
As described in David Latham's memo of 30 June 1983 we have chosen Liberty Coating #756 (attached curves) which peaks at 94% reflectivity in the visible. We expect to begin a program of monthly measuring and cleaning (as necessary) of the mirrors, a program made feasible by the hard overcoating Liberty will install. This may increase the throughput of the telescope by as much as 25% over that in the past and we are eagerly looking forward to being able to maintain and monitor this high level of performance.

It is revealing that the primary was very dusty when it was removed despite having been cleaned two months before. The table below gives reflectivity comparisons.

% Reflectivity

Date	λ3500	λ4500	λ5400	λ7221	Remarks
6/01/83	84%	85%	86%	85%	freshly washed
7/23/83	79%	81%	82%	83%	7 week's dust accumulation.

Front Surface Aluminum Mirror No. 756



Reflection ________

*Measured at Normal Incidence

SMITHSONIAN INSTITUTION
ASTROPHYSICAL OBSERVATORY

PUBLIC INFORMATION
(602) 398-2432

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(602) 629-6741
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FRED LAWRENCE WHIPPLE OBSERVATORY

August 4, 1983

Mr. Tim Conroy
Liberty Mirror
851 Third Avenue
Brachenridge, PA 10514

Dear Mr. Conroy:

The Fred Lawrence Whipple Observatory (FLWO) has placed an order with your company for stripping and recoating of a 60 inch Pyrex primary mirror and an 18 inch Pyrex secondary mirror. This letter documents several points covered in phone calls between our two organizations.

Center Wavelength of Coating

FLWO wants the 756 curve translated so that .3900 microns has a reflectivity of at least 85%. This translation should not, however, move the bottom of the .8300 micron hole lower than .8000 micron.

Witness Plates

Five 1" x 1" witness plates should be returned with the finished mirrors. The base material of these plates is not critical; however, an attempt should be made to locate them near the center of the mirror (in the center hole of the primary) during the coating process.

Testing of Coating

A witness plate coated with the primary will be measured and a curve plotted over the specification curve for comparison. The results of this test will be discussed with FLWO before the mirror is shipped back to FLWO.

Transportation

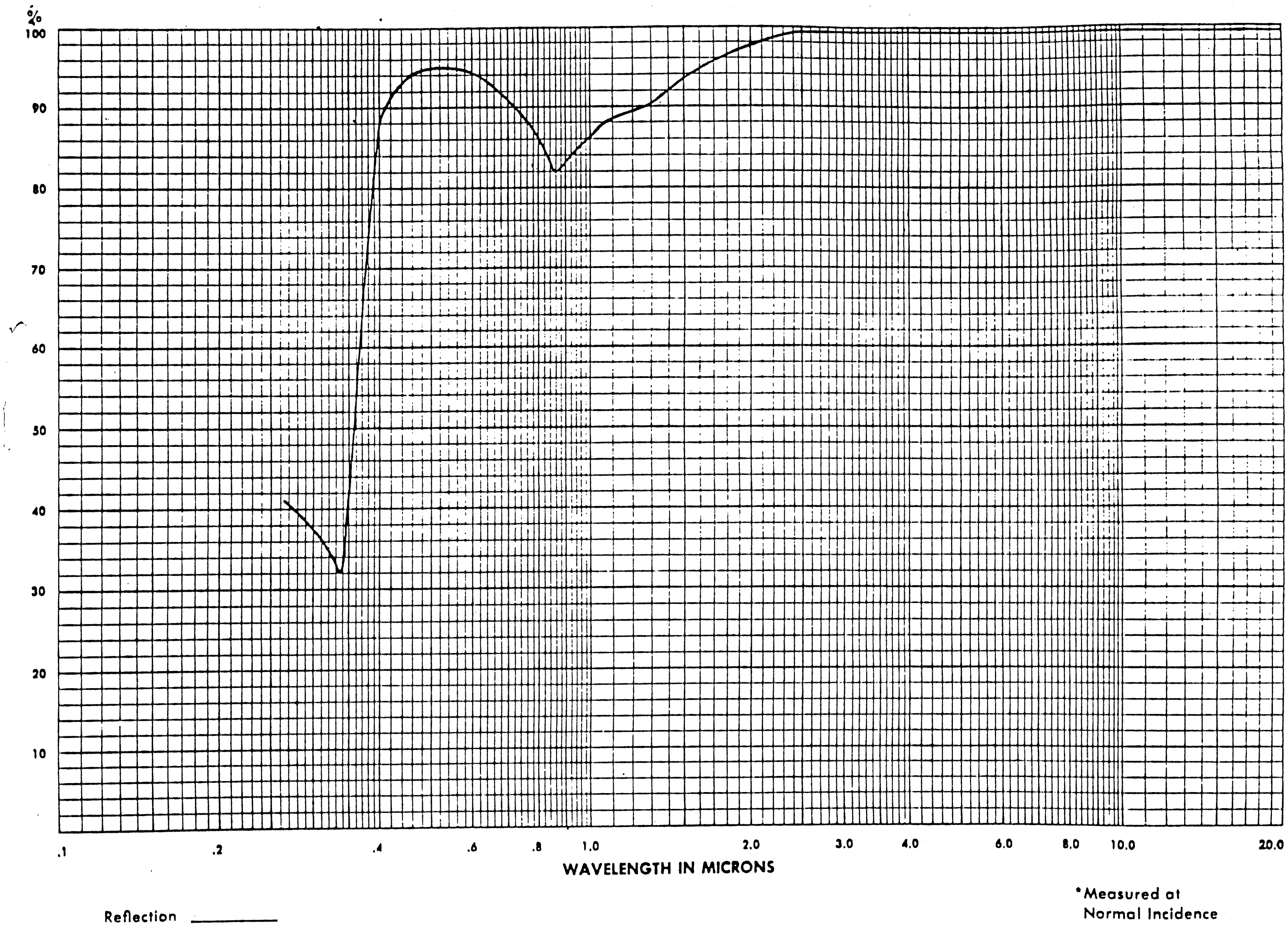
FLWO will provide transportation to and from Liberty Mirror. Liberty will off load and reload the mirror on the FLWO truck.

Stephen J. Criswell

Stephen J. Criswell
Facilities Manager

Attachment
c: F. Chaffee
D. Latham
J. Peters
E. Horine
B. Van't Sant

Front Surface Aluminum Mirror No. 756



*Measured at Normal Incidence

Center for Astrophysics

Harvard College Observatory
Smithsonian Astrophysical Observatory

MEMORANDUM

Bas

June 5, 1990

To: Telescope Instrumentation Committee and other interested parties
From: Daniel Fabricant, Nelson Caldwell, and John Geary
Subject: Preliminary Specifications for a New 60" Spectrograph

Basic Concept

Nelson Caldwell has outlined the status of the existing Tillinghast spectrograph in a companion memo. In this memo, we lay out a set of specifications for the new spectrograph and present an updated project cost estimate. We solicit comments on this plan and in addition, the endorsement of the TIC to begin the project next fiscal year. If we get moving, we could reasonably expect to have a new spectrograph by the fall of 1992. Dan Fabricant and John Geary are willing to oversee construction of the spectrograph in Cambridge, while Nelson Caldwell will consult on the spectrograph design and oversee the modifications required on the telescope.

The spectrograph is designed around a custom Ford CCD with 15μ pixels: 2688×512 pixels, or 40.3×7.7mm. We suggest the adoption of a scale of $0.75''$/pixel and a total spectral coverage from 3650-7300Å with a blue-blazed grating and 4500-8250Å with a red blazed grating. A scale of $0.75''$/pixel would allow the use of slits of 1.5 to $3''$ with sampling between 2-4 pixels.

Design Choices

In order to allow the construction of a small beam, compact spectrograph, we propose to use 600 line gratings as the dispersing element. With a camera focal length of about 180mm, one would obtain resolutions of about 5.6Å (4 pixel sampling) with a $3''$ slit, and about 2.8Å (2 pixel sampling) with a $1.5''$ slit. At the focal plane $0.75''$ corresponds to 56μ; therefore a reduction of 3.7 in the spectrograph is required. The collimator focal length is then fixed at about 670mm, and the beam size at about 67mm given the f/10 focal ratio of the Tillinghast.

We propose to make a long-slit spectrograph. The chip can accommodate a field exceeding $6'$, but a corrector for the telescope is required as outlined in Nelson's memo. We specify a $4'$ field as the nominal requirement.

The collimator can be a simple off-axis parabolic mirror, but in order to avoid serious central obstruction losses, the camera will have to be a custom transmissive design. This camera will be the most expensive single item required for the spectrograph.

Mechanical Details

We plan on keeping the spectrograph mechanically simple and as rigid as possible to avoid flexure. We propose to have only two 600 line gratings available, both mounted simultaneously and manually interchangeable. The slits would defined by aperture plates with positive registration, again manually interchangeable. Provision would be made for mounting filters. The wavelength coverage would be fixed for each grating because we finally have a CCD with enough pixels to cover the entire useful wavelength range. The only remotely controllable part would be the spectrograph focus, but we would attempt to minimize the temperature dependence of the focus.

Top Box

A new top box will be required, containing a fixed, slit-viewing intensified (or cooled) CCD camera with a $4'$ field, calibration lamps, and a comparison mirror. The comparison mirror would be remotely controllable.

Budget

In the following estimate, the cost of the instrument control computer is not included. The hidden salary costs of Fabricant, Geary, Caldwell, and Charlie Hughes are also not included.

Spectrograph and Corrector

Optical design of the corrector	$5K
Optical design of the spectrograph	$5K
Corrector fabrication	$25K
Spectrograph Optics	$50K
Spectrograph Mechanical Design	$50K
Spectrograph Construction	$30K
Top Box Design and Fabrication	$25K
Total with 10% contingency	$210K

Detector and Telescope Upgrades

CCD and Dewer	$30K
Upgrade Telescope Drives	$10K
Miscellaneous	$10K

for more modern spectrographs using CCD's. Because of the red sensitivity of the phosphor, the spectral region shortward of about 4500 Åcannot be observed in any but the brightest sources. This situation is exacerbated by the mirror coatings, which are an overcoated aluminum which has a peak reflectivity of 95% at 5200 Å, but drops steeply off blueward of that, going below 40% at 3500 Å.

SHORTCOMINGS

The drawbacks to the current (and long standing) situation are:

(1) The small field means that long slit measurements cannot be made, thus prohibiting a variety of astronomical projects that require spatial information. Even those that don't require the spatial information to be retained would benefit from an extended slit because more light from the source could be summed along the slit to create the final spectrum. A more accurate estimate of the sky contribution could also be made (currently the sky measurement is no more accurate than the source, if one wants to measure sources near the sky brightness a more accurate measure of the sky must be made).

(2) The tracking/guiding of the telescope is not sufficiently good to keep sources well centered on the slits, thus degrading the spectra.

(3) The lack of good blue response in the spectrum means both that redshift projects are excluded from using perhaps the most useful spectral region for obtaining redshifts, (the 4000 Åregion with the H and K lines) as well as that projects requiring spectra shortward of 4800 Å(say studies of Balmer series in young galaxies) are prohibited entirely.

(4) The spectrograph camera has very little back focal distance, making the installation of a CCD difficult, though not impossible. The current camera has a 20% vignetting of the beam from the obstruction of the schmidt secondary.

IMPROVEMENTS

We now discuss several ways of rectifying these drawbacks, beginning first with the telescope.

The most direct way of improving the field of view is by parabolizing the primary. Combined with refiguring the secondary to the appropriate hyperboloid, a new primary figure would give a field of about 9', at a cost of at least $150,000. That estimate is based on the cost of figuring the 48", and on conversations with ITEK.

Alternatively, one could design and build a corrector, which would reside near the primary vertex and correct the light from the secondary for coma. The estimated cost for this would be about 20% of the cost for refiguring the primary. An additional cost of about $1000 must be added on because we must know the exact optical figure of the current secondary in order to design the appropriate corrector. The primary radius of curvature is believed to be known fairly well, and thus would not have to be measured.

To begin to improve the blue light throughput, the primary and secondary mirrors could be aluminized, regularly of course. Again from an estimate obtained for the 48", the cost for this would be about $1500. Although we haven't done this on the Ridge for quite some time now, we have already committed ourselves to aluminizing the 48", so the work should then only be incremental if both mirrors are done simultaneously. We should expect to aluminize every other year, or more frequently if funds are available.

If we are going to the trouble to improve the optical performance of the telescope, we should also do what we can to improve the mechanical performance. The tracking and guiding of the telescope are currently degraded by the stepper motors used for fine motion. Microstepper motors could be used to increase the precision for fine motion, and at the same time be used for the slewing motion. We estimate $5000 per motor.

The most important thing we can do to improve the spectrograph is to install a CCD, but the current spectrograph camera can be mated to a CCD only with difficulty, and doing so will not solve the problems of field, blue sensitivity, or poor thoughput. A new camera could be built and adapted to the current spectrograph, but the wide field needs could not be addressed (the hole in the grating would have to be enlarged to permit the extra field, but doing so would create more light loss in the collimated beam, everything works against you with this spectrograph). We are thus led to the conclusion that a new spectrograph must be built in order to alleviate the problems outlined above.

Bas van 't Sant

Harvard-Smithsonian Center for Astrophysics

60 Garden Street, Cambridge, MA 02138
Optical and Infrared Astronomy Division

MEMORANDUM
Monday 16 January 1995
Revised 25 January 1995

To: Distribution

From: Dave Latham Dave

Subject: Reflectivity Measurements at the Tillinghast Reflector

This version of my memo is revised to include explicitly the reflectivities that we hope to achieve with coatings applied at the Sunnyside Facility. I have also revised my opinions about the plan to realuminize both the primary and secondary of the Tillinghast Reflector during the period 7-13 February 1995.

Mt. Hopkins was in the clouds this evening, so I took the opportunity to borrow the MMT Reflectometer and measured the reflectivity of both the primary and secondary mirrors at the Tillinghast Reflector. I'd like to thank Brian McLeod, Dan Fabricant, and Nelson Caldwell for their help with these measurements.

We began by measuring the reflectance of a 6x8-inch front-surface mirror which we found in the optics cabinet at the Tillinghast Reflector. We then used this mirror as the reference for the measurements of the telescope mirrors. This allowed us to move back and forth quickly between spots on the telescope mirrors and the calibrated spot on the reference mirror without having to change to the calibration position of the reflectometer. This reduced the effects of lamp drift to a negligible level.

Both of the telescope mirrors had been washed recently (I can't remember seeing them so clean in recent years) and appeared to be in excellent shape to visual inspection. There were no obvious pits or defects on either mirror surface. For the primary we measured three separate positions in each of two triangular areas corresponding to the area under two of the mirror-cover petals separated by 60 degrees. We measured two spots near the outer edge of the primary and one spot near the center of the mirror in each of the two areas. We discovered that the spectral reflectance curve is somewhat different towards the center of the primary compared to the outer edge. The difference was consistent between the two sections we measured. The outer area of the primary is more reflective in the blue and less reflective in the red than the inner part. We speculate that this difference is due to a systematic trend in the thickness of the overcoat as a function of radial distance from the center of the mirror.

Filter	now	sec alum	both alum	*vs* now	*vs* sec al
310	13.6	30.7	85.2	6.26	2.76
380	55.3	78.1	85.4	1.54	1.09
450	83.7	87.9	84.8	1.01	0.96
550	88.0	87.4	83.5	0.95	0.96
700	80.6	82.1	80.8	1.00	0.98

The measurements for 310 and 380 nm should be used with caution. The spectrum of the quartz-halogen lamp is dropping rapidly in this spectral region, and the effective wavelength should be a little longer than the nominal central wavelengths of the interference filters, which have FWHM bandpasses of nominally 12 nm. The shift could easily be 1 or 2 nm. Also, there is a red leak in these filters centered at about 760 nm with peak transmission of about 10^{-5}. These effects could only make the reflectivity at 380 nm look too good. For a careful analysis the contribution of the red leak should be evaluated using the measured transmission curves for these filters explicitly. The measured signal from the reflectometer diode is about 100 times larger at 700 nm than at 380 nm, so 10^{-5} blocking should be quite safe, unless the red leak is much wider than indicated on the generic curves for the 380 filter provided on the manufacturer's spec sheet.

One can use the reflectances quoted here to evaluate the merits of aluminizing just the secondary *versus* aluminizing both the primary and secondary. There can be no doubt that we should redo the secondary. Although the total reflectivity would drop 5% in the green and would hurt the echelle stellar velocity users by that amount, the gain in the near ultraviolet is much larger.

It is less obvious to me that we should also recoat the primary. The gain at 380 nm is less than 10%, and this needs to be weighed against the loss to users at longer wavelengths, typically 2 to 4%. One also has to consider the degradation with time expected for bare aluminum versus the Liberty Mirror 756 coating on the primary, which has proven to be remarkably durable, and has stood up very well to cleaning. If we go to bare aluminum on the primary, we will have to be more careful and more gentle with cleanings, because bare aluminum is much more fragile than the tough overcoated 756. We can also expect the bare aluminum to deteriorate by 1 or 2% over a couple of years, if the experience at the MMT with Sunnyside coatings can be used as a guide. An indication of the kind of deterioration that can be expected for well-aged bare aluminum is given by our measurements for the reference mirror, in the second column of the first table above. Another indication is given by the our measurements of the bare aluminum that we replaced on the primary in 1983. It was 8 years old and peaked at 86%, according to my measurements just before the mirrors were shipped to Liberty Mirror.