CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE MODIFICATIONS

The tip/tilt system to date has greatly increased the efficiency of the Shane telescope during bad seeing conditions, has had no adverse effects on the data obtained, and has nearly eliminated the chances of the star being lost during an observation. The system also allows the telescope to be pointed at new objects more efficiently by pulling the star into the slit faster than can be done by a telescope operator. Once the mirrors on the optical table are recoated, with the more efficient FSS-99 Silver coating from Denton Vacuum, the throughput of the telescope should be increased for all seeing conditions. The expected mean increase was determined, using test optical coatings, to be between 23% and 140% depending on seeing conditions. The increase will tend to be smaller during good seeing because the image is more stable during these conditions. The tip/tilt system performs at its best during bad seeing, reaching throughput gains as high as 170%. The system also makes it possible to observe during seeing conditions that normally require the observer to quit for the night due to insufficient signal to noise ratios caused by bad seeing.

The system has been shown to be completely aligned, using a laser in the daytime to save observing time, in less than 15 minutes. The alignment sometimes requires an additional 1-3 minutes of fine tuning using the first star of the night. Although the system will be aligned and run by the telescope technicians and telescope operator, it is easy enough to be operated by the observers as well.

The system is currently ready for use, but there are a few remaining details that need to be completed as summarized below. These objectives were put on hold because they are not critical to the operation of the system for testing purposes but will be completed before the first observing run that will use tip/tilt on a full time basis in late December.

- Install new mirrors with Ag coatings when received from Denton Vacuum.
- Build housing for optical table or mirror covers.
- Modify TELCO controller to read the correction signals outputted from tip/tilt
- Complete the SiPD circuit for safer operation of the PMT.

There are also a number of future modifications that should be considered to increase the performance and ease of operation of the system. The first two, motorizing the beamsplitter mount and installating a system gain adjuster in ROR, are strongly recommended to be done immediately:

- Motorize beamsplitter mount for easier alignment. The micrometer adjusters on the kinematic stage can be directly replaced with picomotors from New Focus. The picomotors can be controlled with a joystick from the Shane ROR (Read Out Room) and would make alignment possible in a much shorter time period on the first star of each night. Rolling the optical table into place and installing the beamsplitter have shown that the object should be on the PMT surface. During closed loop operation with a star, the picomotors can be adjusted with the joystick until the object is located on the slit as viewed on the ROR monitor. A program could also be created to automate this alignment procedure. Picomotors are low cost piezoelectric driven motors with pm resolution. They are designed for direct replacement of micrometer adjusters on adjustable stages. The total cost for two picomotors, a joystick and a driver is approximately $1865.

- The correction gain, K from equations (33) and (34), can be adjusted manually by installing a potentiometer in the Shane ROR. The controller would then evaluate the magnitude of the returned voltage signal to determine the gain. This would help optimize corrections for various seeing conditions. Currently all analog outputs are in use on the I/O board. The output signal could be a TTL signal from one of the open channels on the digital output port. A second analog output board (PCI-20093W-1) has also been installed in the PC for additional outputs if necessary. This board could be utilized to output this signal as well, or an external power supply could be used. By installing this option, the gain could be adjusted during observations should the star begin to jump around or the system begins correcting too slow. It may also be possible to develop an algorithm within the current controller to adaptively adjust the gain during closed loop operation.

- Replace the PMT with a better position sensor. An absolute position measurement, regardless of image size, would help the controller make single step corrections. This can be achieved using a position sensitive PMT or a fast read out CCD. The position sensitive PMT (available from Hamamatsu) has a slightly lower QE (quantum efficiency) than the current PMT, further limiting the range of observable stars. Fast read out CCDs and image intensified CCDs should be researched to determine if they would be a viable replacement. Another option is to replace the current TELCO CCD with a fast read out CCD to be used for both TELCO and tip/tilt.

- The current TELCO CCD uses light reflected from the aperture plate to determine the position of the image. It may be possible to use a fraction of this light to illuminate the PMT. This would eliminate the 6% light loss from the beamsplitter in the incoming light path to the Hamilton Spectrograph. The light is reflected from the aperture plate, resulting in an image with rectangular hole in it caused by the slit. The odd shape would have to be compensated for in the programming.

- The diaphragm in the PMT baffle tube should be replaced with an electronic shutter. This would allow the controller to open the shutter only during use of the PMT, further protecting it from external light. It has not yet been decided if the mirrors of the optical table will have individual covers or a complete optical table housing. If a housing is used, electronic shutters should be placed in the light path entry and exit ports. These ports could also be covered using windows with anti-reflectance coatings.

- The efficiency of the system could be increased by increasing the system bandwidth. By replacing the tip/tilt control feedback loop with an analog controller and replacing the tip/tilt mount with a voice coil actuated mount, the bandwidth could be increased to the kHz level. The remaining control features could remain as is in their current digital formats. A voice coil actuated stage that meets the system requirements is available from Ball Corporation for about $15,000. This option is probably overkill, as the system is currently fast enough for most seeing conditions, but could be achieved for under $25,000.