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Smithsonian Institution &
The University of Arizona®

Elevation Servo Review Committee Report

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Summary

This committee was asked to review the progress made in developing a new elevation axis servo system, judge its current performance, and make recommendations for ways it might be improved. We (on the committee) feel, first and foremost, that this charge can only be fully carried out against the backdrop of a scientifically justifiable specification. We were given two indications of desired performance: 1) the 'Tracking and Drives' section of the error budget given in the original conversion document (Fabricant, McLeod, & West 1999) and 2) a recent memo from the MMT Council specifying a number that's 5% of some 'best seeing'. No strong scientific justification is given for either number, the numbers don't make any clear allowance for wind speed/direction, and they don't make any distinction between tracking errors due to the servo and those due to the telescope structure itself. There are well-known and significant resonances in the MMT's structure that must be minimized, but can't be eliminated by any servo design.

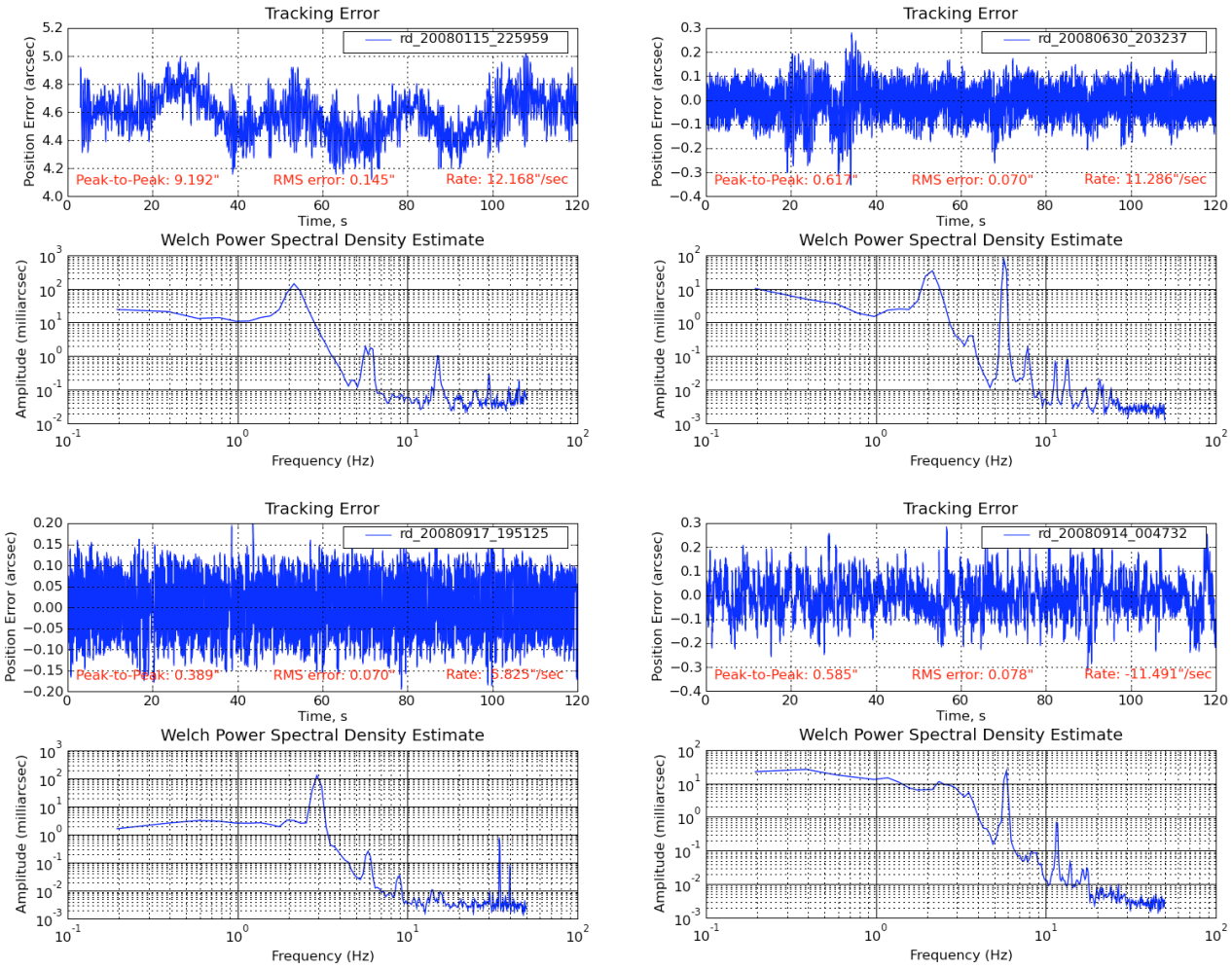
In spite of this lack of a clear target against which to ultimately judge the performance of the mount servo system, we are still in a position to make judgements against past performance and the performance of other telescopes under similar conditions. It was clear from the presented data that the original LM628-based servo system suffered from a very serious drawback: amplification of resonant structural modes and the lack of any ability to filter them out. This greatly limited the stiffness of the servo which in turn significantly degraded tracking performance in the presence of wind. The performance was visibly bad at times with peak-to-peak tracking errors of 2" or worse even under modestly windy conditions. Improving tracking performance required filtering of the resonant structural modes which was not possible with the LM628 system. This requirement was the primary motivation behind the design of an entirely new elevation servo architecture.

We find no obvious problems with the high-level design or architecture of the new servo system. The tools and methods used are fairly well-established industry standards. However, the system is sufficiently complex that the committee was not really able to penetrate its design and architecture to a level that would allow us to make detailed suggestions about it. Based on the very thorough presentations that were given by the MMTO staff involved in the project we're comfortable that they have a good understanding of the project and the issues involved in it.

The new servo system was fully deployed in November 2007 and has been in routine operation since then. Unfortunately, it did not immediately provide the hoped for improvement in performance. The main problem was low frequency (2-3 Hz) gain-peaking due to a mismatch between the plant model in the servo and the actual telescope. This was identified and work was performed over the course of Spring 2008 to develop and implement an improved model. This was then deployed over the course

of Summer 2008 along with disturbance decoupling to further improve performance under windy conditions.

Due to weather and summer shutdown, early September 2008 was the first opportunity to judge on sky the performance of the new servo system with known issues fixed and disturbance decoupling enabled. The early indications are promising. The plots below show a couple of examples of current performance along with a couple from earlier in the year for comparison. These results are representative of the performance that has been seen so far. The RMS servo tracking error has consistently been 0.1" or better under even fairly windy (20-30 mph) conditions. This is a significant improvement over



Examples of Elevation Tracking Data
Upper Left: *January 15, 2008 pointing about 180° away from 25-30 mph winds.*
Upper Right: *June 30, 2008 pointing into 5-10 mph winds.*
Lower Left: *September 17, 2008 pointing about 90° away from 10-15 mph winds.*
Lower Right: *September 14, 2008 pointing about 180° away from 20-25 mph winds.*

the original LM628 system and competitive to, if not better than, the performance of other large telescopes as quoted in the MMT Council's memo.

Conclusions & Recommendations

Given the current observed tracking performance, the committee feels that MMT's mount elevation servo system is now working very close to how it was originally intended to. The most significant problems that attracted the most attention from the MMT observer community appear to have been solved. An ultimate judgement cannot be made, however, without a more comprehensive tracking performance specification that takes into account wind speed and tracking error components other than the servo. The committee would like to make the following specific recommendations:

- The MMT observing community needs to work with the MMTO to come up with a comprehensive and science-driven specification for tracking performance. It must recognize that tracking performance measured at the focal plane is not driven completely by the performance of the servo systems. In fact, the servo systems may not ultimately be the limiting factor. It must also take wind speed into account. It is not reasonable to expect the same performance in 30 mph winds that you would get in 10 mph winds.
- It was apparent to the committee that the elevation servo's progress suffered from lack of access to the telescope for night-time engineering. We recommend that much greater effort be made in the future to set aside time for servo engineering and mount performance profiling. This will be especially important once work begins on the development of improved servos for the other axes. There are already several M&E nights scheduled during Fall 2008 that would be appropriate and we highly recommend that they be utilized for this work. Specific needs are further tuning of the 2-3 Hz peak, a new pointing model that incorporates the tape encoders, and some focal plane tracking data to compare with the servo encoder results.
- Work should be done to streamline the deployment of models developed under simulink/xpctarget into the vxworks environment that runs the telescope. It seems likely that the telescope model used in the servo system may need refinement over time. Telescopes change and there are very heavy instruments slated to be delivered to the MMT over the next few years. It will also benefit the development of new servo systems for the azimuth and rotation axes.
- A servo test and validation procedure should be developed and followed whenever a significant change is made to the system. The tests should validate safety as well as performance. A draft of such a procedure was presented to the committee and we encourage the MMT staff to flesh it out and implement it.

- Tracking performance data should be collected as routinely as possible and communicated back to the MMT observer community. The servo data is already routinely collected and presented for MMT staff use. Methods for more routine measurements of focal plane tracking performance should be investigated (e.g. mounting accelerometers at the back of the telescope near the rotator mounting).