MROI Delay Line Final Design Review
Review Panel Report

Theo ten Brummelaar, Chairman (CHARA/GSU)
Fredrick Derie (VLTI/ESO)
Robert Ligon (Keck/JPL)

1 Introduction

On the 12th of February 2008 the Final Design Review (FDR) for the Delay Lines (DL) for the Magdalena Ridge Observatory Interferometer (MROI) was held in the Cavendish Laboratories of the School of Physics at the University of Cambridge. Present at the meeting were:

Review Panel

Theo ten Brummelaar: Center for High Angular Resolution Astronomy.
Frederic Derie: European Southern Observatory.
Robert Ligon: Jet Propulsion Laboratory.

Cambridge DL Design Group

Chris Haniff: Professor of Physics, DL design group leader & MROI System Architect.
David Buscher: Lecturer in Physics & MROI System Architect.
Fabien Baron: Research Associate & Optical Engineering.
Roger Boysen: Senior Technical Officer & Metrology.
Martin Fisher: Senior Research Associate & Systems and Controls Engineer.
Bodie Seneta: Research Associate & Software Development.
David Sun: Research Associate & Mechanical Engineering.
Donald Wilson: Emeritus & Electrical and Mechanical.
John Young: Senior Research Associate & Software Development.

New Mexico Tech/MROI

Van Romero: Vice President for R&ED.
Eric Baker: MROI Project Manager.
Fernando Santoro: MROI Lead Opto-Mechanical Engineer.
Thomas Colman: MROI Lead Software Engineer.

Other Participants

Steve Traver: Congressional Fellow
Sergio Restaino: Navel Research Laboratory

The MRO document INT-206-TSP-002 sets out the top-level requirements of the delay line system and the tests results are described in documents INT-406-VEN-0108 and INT-406-VEN-0109, available on the Cambridge team WiKi site[1]. The review panel were given the goals of answering the following questions:

1. Does the design meet the criteria set out in INT-206-TSP-002?
2. Does the performance of the prototype also meet these criteria?
3. Is the 20m test rig sufficient for confirming the performance of the prototype delay line?
4. Have all the known hazards and risks been considered in the design?

The panel was also asked to

1. Provide our opinions on the MROI delay line system.
2. Be critical and constructive.
3. Compile this report.

After introductions by Dr. Haniff and Dr. Bakker, the single day meeting consisted of a half day of presentations and discussions concerning the design of the delay line and the performance tests conducted on the prototype to date, and a half day inspection of the site of the test bed system. This was followed by discussions amongst the review panel members. Final notes were forwarded to the panel chairman, who then drafted this document. This draft was then circulated amongst the review panel and corrections and additions made before submitting the final report to MROI.

2 Summary of Findings

The design criteria for the MROI delay line are essentially the same as those for the delay lines in other existing interferometers. Apart from the concerns discussed below, mostly concerned with moving from a 20m test bed to a full 200m delay line and based on the material presented to us during the design review, the panel concludes that:

1. The delay line design meets all requirements and functions set out in the specification documents which are themselves sufficient to ensure the proper functioning of the Interferometer.

[1]http://www.mrao.cam.ac.uk/∼jsy1001/pmwiki/pmwiki.php.

2. The performance of the prototype delay line meets all requirements and functions set out in the specification documents.

3. We find that the test rig is sufficient for confirming the performance of the prototype delay line.

4. The panel knows of no hazards or health risks associated with the design that have not been properly considered by the design team.

We recommend proceeding to the production phase of the delay line system.

3 Recommendations for the Finalization of the FDR.

While the panel is confident that the design and prototype meet the stated requirements, a number of issues were raised during the review that need attention in the near future. We believe it is possible to conduct these tests in parallel with and without delaying the production phase of the delay line carts.

3.1 Confirmation of the Optical Quality and Coupling of Delay.

The panel are concerned that no direct tests of the optical quality of the prototype delay line cart were reported in the tests results document. In particular the addition of tip/tilt control of the cat's eye secondary and the mounting of the primary mirror are features unique to this system and there is a small risk that they can cause a decoupling of the optical delay in the metrology and science channels, as well a degradation of the optical quality of the science beam. We recommend that the Cambridge team confirm that the the prototype meets the specified optical quality and that the science and metrology optical delay are coupled to better than the tracking specification of the delay line system. Ideally this should be done with direct measurements of the prototype, though it is possible that this could be demonstrated using a combination of optical tests of the delay cart optics and ray-tracing of the system.

3.2 Upgrading the Steering System.

The current step size of the steering control system of the delay carts is too large and causes tracking errors when the steering servo is engaged. The panel understands that this problem will be solved either by time tagging these tracking errors and flagging the science data stream and/or by modifying the control system and reducing the step size of this servo. The panel believes that the flagging of on-sky data should be a last resort and that the design team should pursue the hardware solution. The ability of this new system to remove the tracking errors while steering the cart needs to be demonstrated before proceeding with the production version of the delay line carts.

3.3 Power Spectral Density Analysis of Cart Performance.

Only one plot of the Power Spectral Density of the metrology error signal is presented for a tracking speed of -1mmS^{-1} in the test results document. This PSD shows a peak near 22Hz, a possible resonance of the system, although there is no direct evidence that this resonance degrades the performance of the system beyond the specified performance limits. The panel recommends that a PSD analysis be performed on the existing data set of the full range of the specified cart velocities, -15mmS^{-1} to $+15\text{mmS}^{-1}$, in order to confirm that this peak in spectrum either does, or does not, exist at all velocities and that any resonances in the system either do not constitute a serious degradation of delay line performance, or can be removed by an adjustment of the servo tuning parameters.

3.4 Test Rig Performance Under Vacuum.

No tests of the performance of the prototype delay line cart under vacuum conditions were presented at the design review. We recommend that these tests be performed as soon as possible in order to demonstrate that the performance of the delay line is not compromised by operation under vacuum.

3.5 Simulations of Long Slews not Currently Accommodated by the Test Rig.

The current test rig length is 20m, representing only 10% of the specified length of the production version of the delay. One of the risks associated with increasing the delay length is the failure of the metrology, including counter overruns, during long slews of the cart. We recommend that tests using simulations of long slews on the testbed system be performed to confirm that the risk of metrology loss is low.

4 Recommendations for the Production Phase.

During discussions at the review a number of potential risks were identified for the production phase, mostly associated with the large increase in cart path from 20m to 200m. As part of our charge to "provide our opinions on the MROI delay line system" the review panel would like to submit some recommendations in the hope of helping reduce these risks. It should be noted that these recommendations are intended to aid in the progress of the production phase of the delay line carts, not delay it.

4.1 Support Pipes: Good Joints/Bad Joints

The tests results of the prototype rig clearly showed that if the support pipes and joints of the delay lines do not meet the specification large tracking errors can occur when the cart is driven over a "bad joint" and that the prototype performs well within specification when driven over a "good joint". There was a great deal of discussion concerning the manufacture, procurement and installation of these pipes during, and after, the review and we see this as a source of risk in the production version of the delay lines. The final pipes installed must meet the specification or the delay line performance will be compromised. This should include ensuring that the pipe joints and pipe alignment meet the specification. This is a procurement and installment issue for MROI and we recommend that discussions between the NMT and Cambridge teams continue in order to clarify the possible methods of production and installation of the support pipes. We also highlight the fact that the specification will be limited by post-production handling of the pipes. These will be large and heavy segments of metal and special handling procedures will be required. In order to limit shipping risks, we suggest that a US manufacturer would be preferable.

4.2 Final Choice of the Metrology Laser Head.

One of the risks involved in moving to the full 200m path length is the unprecedented long propagation length, and consequently the coherence length and frequency stability required of the metrology system. If the Agilent laser passes the frequency stability requirement tests now in progress, they will be the only laser manufacturer identified, and there is a small risk that this laser will not pass these tests. We recommend that MROI and Cambridge perform a risk reduction study to investigate if the limits of the existing Zygo lasers are tolerable, and what other lasers can be pursued.

4.3 Servo Tuning and the Use of "Digipots" in the Delay Servo.

It is the review panel's understanding that the prototype servo systems are tuned, at least in part, by the manipulation of small potentiometers on the cart itself and that these will be replaced in the production carts by "digipots" capable of digital control. This is a very low risk change, however we recommend that tests be performed on this new system as early as possible during the production phase of the delay lines. Furthermore, as part of the knowledge transfer discussed below, we recommend that MROI ensure that the documentation supplied with the production carts includes a complete description of servo methods, analysis methodology, and tuning techniques.

5 Recommendations to MROI Beyond the FDR.

Given that the design phase is complete and that the production phase will soon begin the review panel would like to submit further recommendations beyond the scope of the FDR.

5.1 Knowledge Transfer.

It is vital that there is a complete knowledge base at MROI in order to enable long term support and possible future improvements of the delay line systems. We recommend that MROI consider locating a controls or software engineer with the Cambridge group for several months to work within the delay line production team. This engineer would work closely with the Cambridge group and will have the opportunity to become intimately familiar with the delay line hardware and control systems, as well as ensure that the final documentation is complete, in a way that is not otherwise possible thereby mitigating the risks involved in the transfer of knowledge from Cambridge to MROI.

5.2 Control Software.

The control software of the test rig, and the production version, of the delay line was not part of the initial agreement between MROI and Cambridge. However, a full re-engineering of the delay software by MROI represents a large risk. The existing test bed software is capable of running a single cart and meeting all requirements of the production delay line system, and it should be possible for the Cambridge software engineers to expand the existing software base so that it is capable of controlling multiple carts. All that would then be required is an interface between this existing Cambridge code and the MROI control system. This work would form a natural part of the work of the visiting engineer discussed in section 5.1. In the longer term, control code more compliant with internal MROI software standards could be developed without compromising the scientific output of the array.

5.3 Full 200m Pipe Tests.

It has already been stated that we believe that the major risks associated with the full deployment of the MROI delay line system are to a large degree predicated on the move from a 20m test bed to the full 200m system, or systems. We recommend that MROI start the procurement and installation of a full 200m pipe line for the testing of the first production delay line on site as soon as possible. This will help ensure the successful development of a critical and expensive part of the interferometric system.

5.4 The NMT/Cambridge Relationship

We understand the need for a managed development model, including complete requirement specifications and external design reviews, and commend the MROI and Cambridge teams on the design path and the nature of this review process. Given that members of the Cambridge design team are also System Architects for the Interferometer itself, we feel the need to point out the risk of allowing the relationship between NMT and the Cambridge team to become one of an adversarial client/vendor nature. Many of the long term risks, and in particular those related to knowledge transfer and corporate knowledge infrastructure, can be mitigated by ensuring that NMT and Cambridge continue to work as partners in a long term and scientifically fruitful collaboration.

6 Conclusion

Based on the material presented to us at this design review, we believe that both the design of the delay line cart and the test rig are sound and meet or exceed the stated requirements. We recommend moving ahead with the production phase of the delay line carts as soon as possible. We thank MROI for this opportunity to help in the development of this new and exciting interferometer.