MROI's Automated Alignment System

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ABSTRACT

The Magdalena Ridge Observatory Interferometer (MROI) will be a reconfigurable (7.5-345 meter baselines) 10 element optical/near-infrared imaging interferometer atop Magdalena Ridge, 30 miles west of Socorro, NM. Depending on the location of each unit telescope, light can travel distances ranging from meters via several reflections that redirect the beam's path through the beam relay trains, delay lines460 to 660 , beam reducing telescope, switchyards and finally to the beam combiners. All of these sub-systems comprise the three major optical axes of the MROI defined by the unit telescope (UT), the delay lines and the beam reducer (DL/BR), and the beam combiners (BC). The purpose of the alignment system is to provide a method of coaligning these three axes. One major obstacle in designing the automated alignment system (AAS) is the required simultaneous measurements from the visible through near-IR wavelengths. Another difficulty is making it fully automated, which has not been accomplished at other optical/near-IR interferometers. The conceptual design of the automated alignment system has been completed and is currently in its preliminary design phase. Prototyping has also commenced with designs of some hardware near completion. Here is presented the current outline and progress of MROI's automated alignment system design and some results of the prototyping.

INTRODUCTION

The MROI is comprised three major optical axes defined by the unit telescope UT), the delay line/beam compressor (DL/BCR), and the beam combiners (BC) (Figure 1). The DL and the BR are considered to be on the same optical axis because there are no turning mirrors between the two systems. *The purpose of the AAS is to provide a method for coaligning these three axes.*

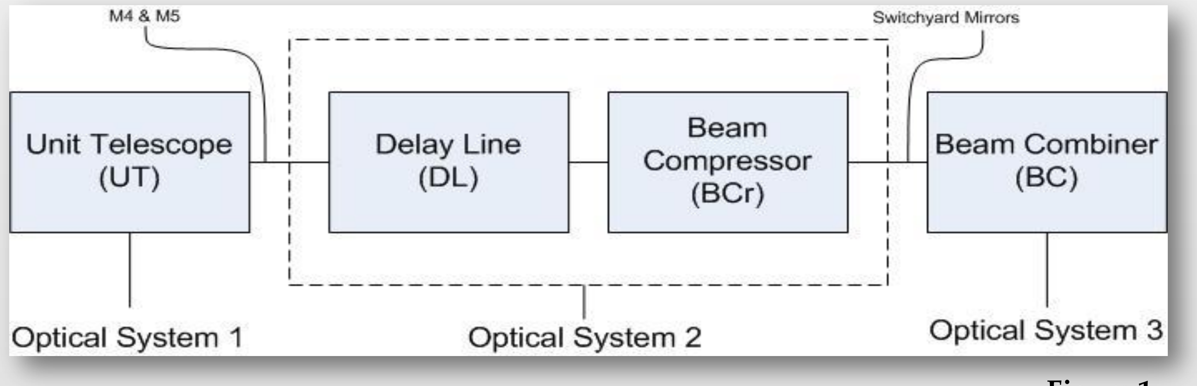
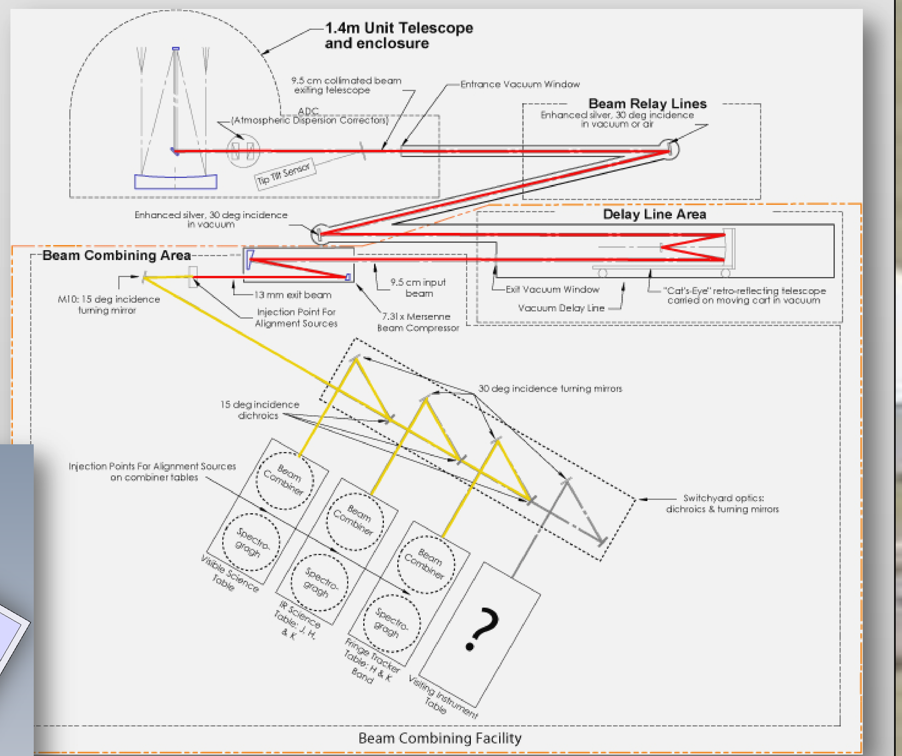


Figure 1

Depending on the location of the UT from start to finish the beam will travel distances ranging from 460 to 660 meters via several reflections that redirect the beam's path through the beam train into the delay line area (DLA) and finally into the beam combining area (BCA).

Figure 2 A 2-D schematic of the MROI optical train from the UT to the beam combiners. Light collected from the source by the UT is propagated through the beam relay (BR), to the delay lines (DL), and into the inner BCA. The red and yellow lines represent the primary fiducial light sources' paths (see Design section).



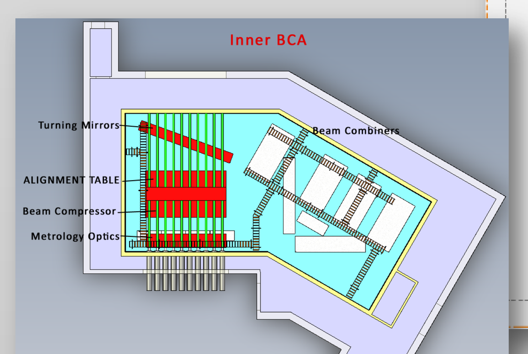


Figure 3 A top view of the inner BCA and the location of the Alignment (primary fiducial) bench.

The BCs are will be comprised of four beam combining tables that will simultaneously operate at visible and IR wavelengths, with one undetermined visitor instrument table. The first table will be for visible science, the second table will be for IR science (in J, H, and K bands), and the third table will be for fringe tracking (in H and Ks bands). A switchyard system will be located in front of each beam combining table and will consist of dichroics and turning mirrors optimized for the different bandpasses. Current discussions of the AAS omit the visiting instrument and its switchyard.

Wavelength, λ,(μm)	Bandpass	Beam Combiner
0.656	H_α	Visible
1.1 – 1.39	J	IR Science
1.5 – 1.8	H	IR Science, FT
2.0 – 2.4	K	IR Science
1.99 – 2.31	K_s	FT

Table 1 Table is the operating wavelengths of the beam combiners for the MROI.

Table 2 Lists the names, locations, and shape of the optical components. A pair of turning mirrors are necessary to correct tilt (angular) and shear (translational) errors between the three optical axes of the interferometer (see Figure 1).

MROI Name	Component Name	Location	Shape
M1	UT Primary	UT Structure	Parabolic
M2	UT Secondary	UT Structure	Parabolic
M3	UT Tertiary	UT Structure	Flat
M4	**Beam Relay Flat 1**	**Beam Relay**	**Flat**
M5	**Beam Relay Flat 2**	**Beam Relay**	**Flat**
M6	Cats-Eye Primary	DL Cart	Parabolic
M7	Cats-Eye Secondary	DL Cart	Flat
M8	Beam Reducer Primary	BCA	Off Axis Parabolic
M9	Beam Reducer Secondary	BCA	Off Axis Parabolic
M10	BC Turning Mirror	BCA	Flat
M11(VIS/FT/IR) thru M16	**Switchyard Components**	**BCA**	**Dichroics & Flats**

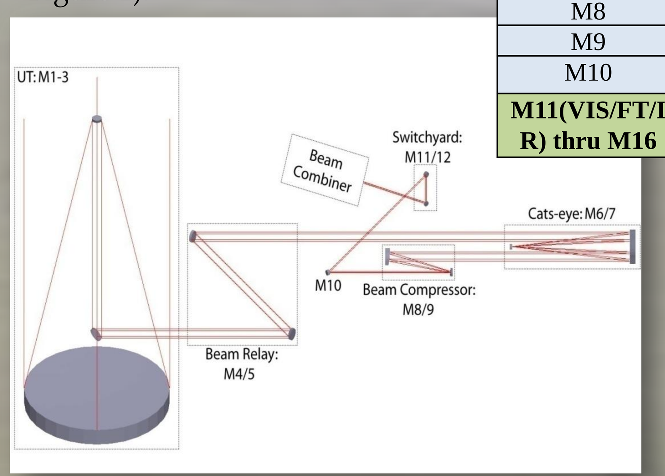


Figure 4 A ray trace that highlights the 6 optical assemblies that make up a single beam train of the interferometer to the first switchyard. The beam path proceeding downstream starts at the UT and goes through the beam relay, then to the cats-eye (DL), the BCR, a turning mirror M10, the switchyard, and finally the BC.

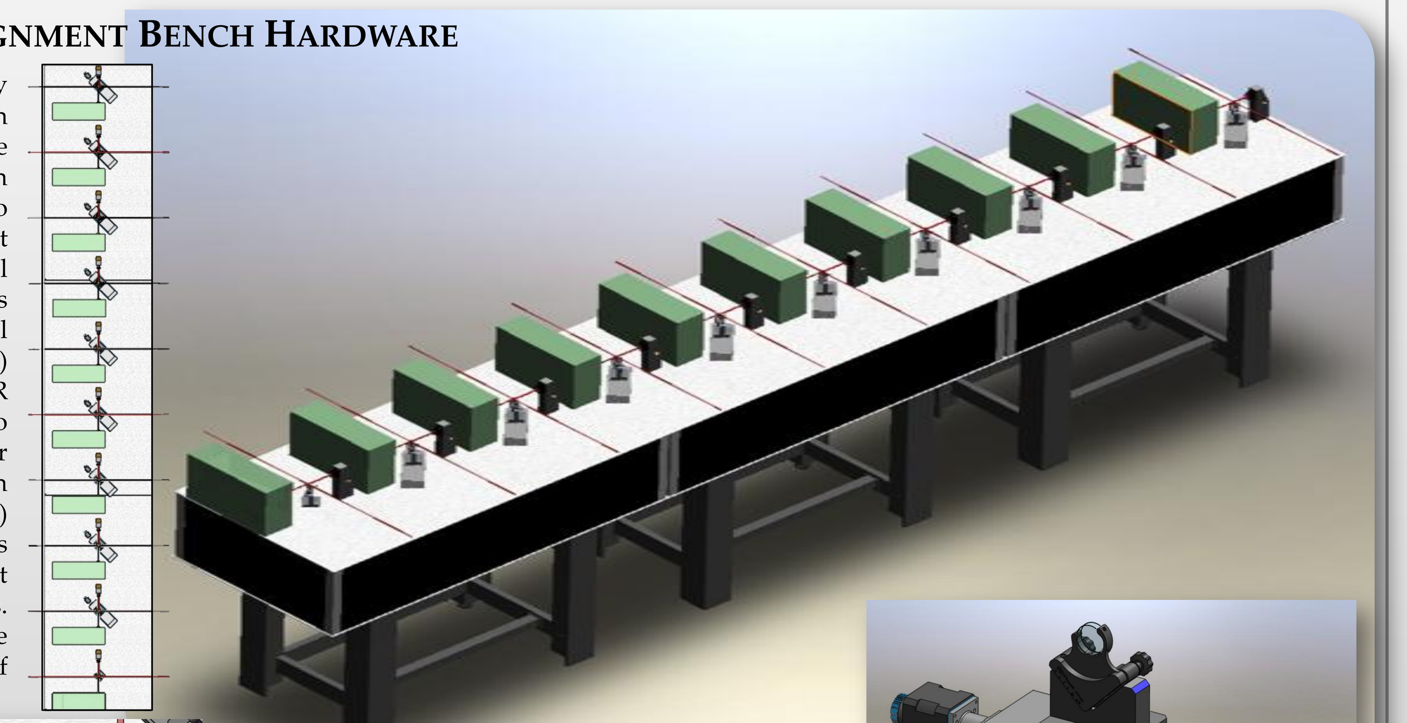
Finally it is important to define the key components of the AAS. The Design section of this poster describes these components in more detail.

:: Primary Fiducial
:: UT Nasmyth Table Hardware
:: Beam Combiner (Fringe Tracker) Hardware
:: Secondary Fiducial
:: AAS Engine

DESIGN

Primary Fiducial – Alignment Bench Hardware

Figure 5 The purpose of the primary fiducial is to establish a reference axis, in this case the DL/BCR axis, to which the UT and BC axes must be coaligned. An LD (635nm) beam is intended to travel to the UT upstream, and a white light (broadband) source is intended to travel to the BCs downstream. The light sources will be located in a collimating optical setup dubbed as the MOB (Figure 6) located in front of each beamsplitter/CCR setup. Each beamsplitter (or a slide to move in/out of the beams' path for alignment/observation modes and with tip/tilt actuation for fiducial alignment) represents each UT beam line. A CCR is located after each beamsplitter to redirect the MOB beam downstream to the BCs. The beamsplitters are located in the optical path with a 45° angle of incidence.



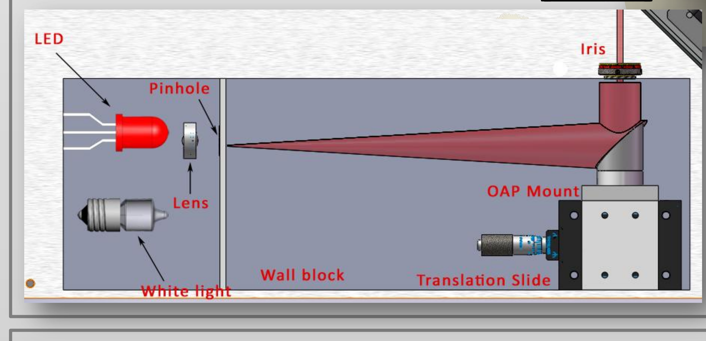


Figure 6 The MOB ensures that the LD and the broadband beams are collimated, stopped down to the same diameter, and follow the same optical path. It is crucial that each individual MOB beamsplitter/CCR assembly is aligned to each DL for proper fiducial alignment.

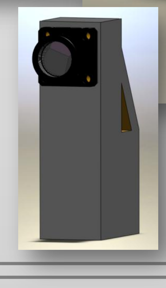


Figure 7 CCR and beamsplitter assemblies.

Tilt and Shear Measurement/Correction at UT – UT Nasmyth Table Alignment Hardware

Detection and measurement of tilt and shear errors between the UT and the DL/BCR optical axes will take place on the Nasmyth Table of the UT. M4 and M5 in the beam relay will be used to remove the tilt and shear errors.

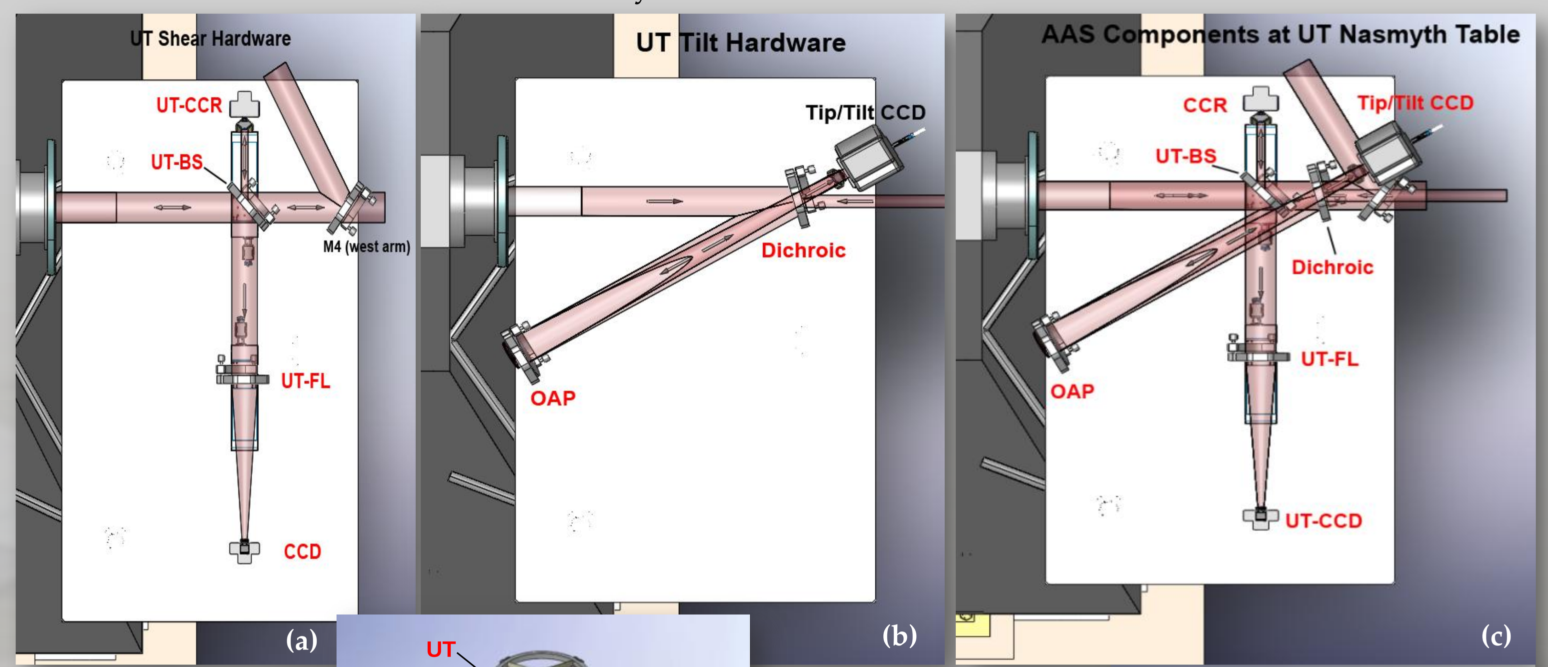


Figure 8 **(a)** Top view of the Nasmyth Table showing the **shear measurement hardware**. Light from LEDs surrounding the UT primary mirror enter the Nasmyth Table from the left where it is reflected by the UT-BS to the focusing lens, re-imaging the UT pupil onto a CCD. The same is done with the primary fiducial LD. **(b) UT tilt measurement** hardware utilizes the hardware for the FTT system. First, M3 is moved into retro-reflection mode. Two spots from the primary fiducial are focused onto FTT CCD. One of them gets directed there by the 1st reflection off the dichroic, and the second is transmitted through the dichroic and reflected back by M3. **(c) All AAS components**.

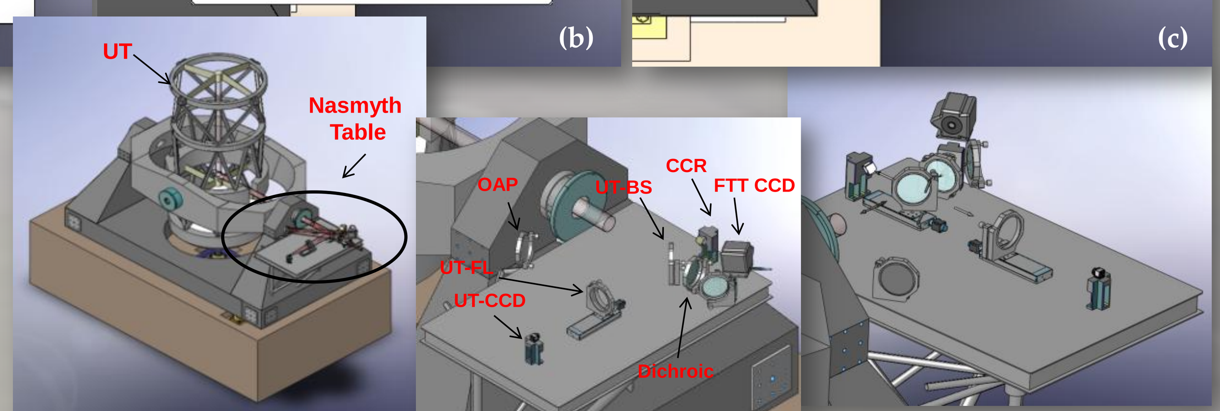
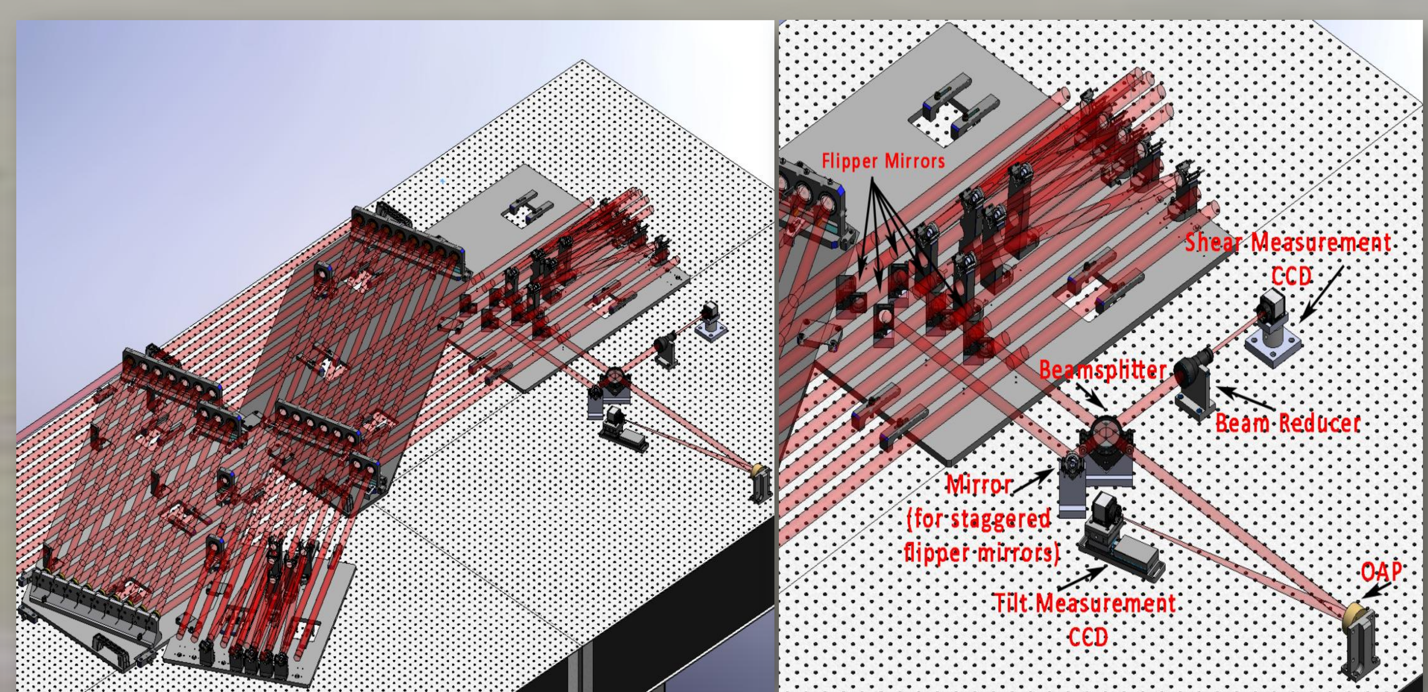


Figure 9 Views of the Nasmyth Table along the side of the UT from various angles with all AAS components showing.

Tilt and Shear Measurement/Correction at BCs – FT Alignment Hardware

In order to align the FT BC axis to the DL/BCR axis the white light source must be switched on. Shutters (not shown) located in front of the BC ports will open or close to select light corresponding to that from a UT of interest.

Figure 10 The beams at the FT table are diverted from their path to tilt and shear detectors. The fringe tracker beam combiner is designed so that it combines light from nearest neighbor telescopes, so for 10 telescopes (i.e. 10 beams at the combiner input) there are 9 combined output beams. There will be a total of 9 ("flipper") mirrors located at combiner output 1 which will divert the beams toward a beamsplitter. This beamsplitter reflects a portion of the beam to a 6x beam reducer for shear measurements and transmits the other portion of the beam to an OAP for tilt measurements.



AAS Engine – "The AAS Brain"

The AAS engine (a.k.a. ACS) has several primary functions which include the following:

- Perform the alignment procedure in an appropriate set sequence
- Receive raw data from detectors → perform centroiding calculations → determine centroiding errors
- Feed appropriate offset values to M4/M5 and to SY optics for tilt/shear corrections → recheck alignment again by receiving raw data from detectors → perform centroiding calculations to confirm alignment
- A mode to perform "quick checks" using pop-up quad cells
- Pass data to the archiving system
- Pass data to the user interface

The AAS Engine will perform these tasks and procedures remotely, that is, all the tasks of the AAS which include initiation of the system, measurements, and corrections must be achieved from the control center i.e. user interface. This must be done in a fully automated fashion, that is when the AAS is set to run the alignment, it does the whole sequence of alignment without the need for human intervention. There will also be a manual mode available for troubleshooting.

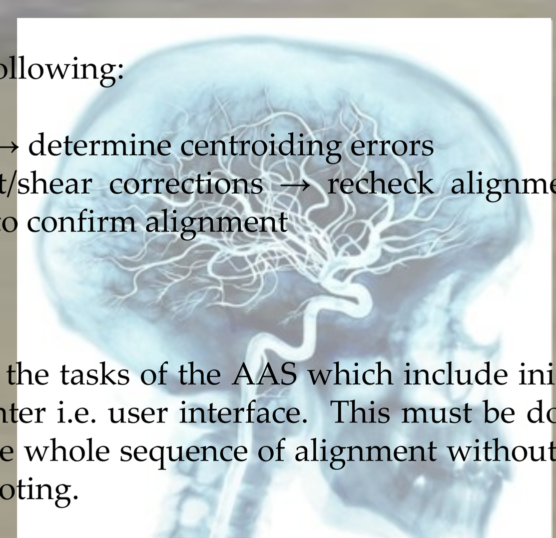


TABLE OF ACRONYMS

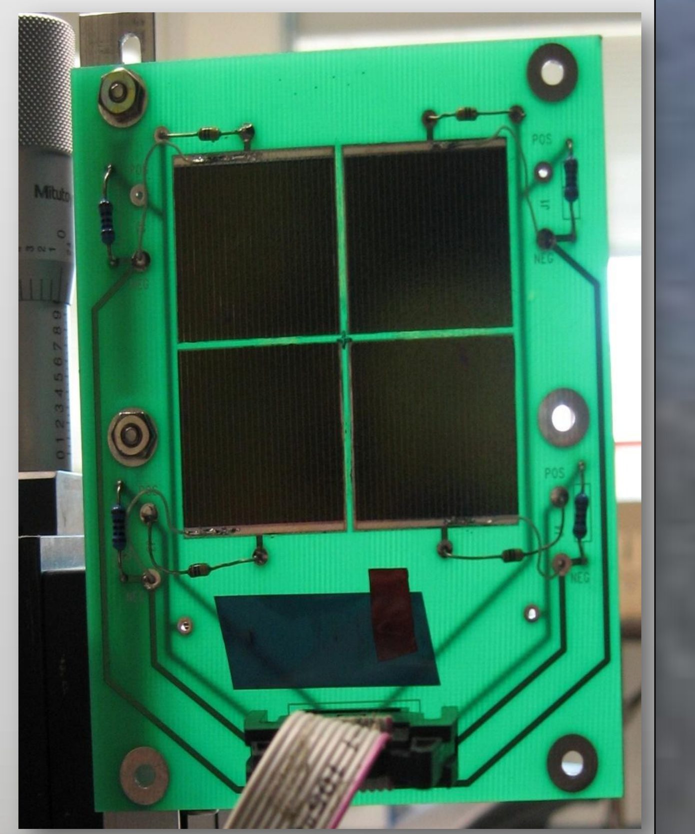
AAS	Automated Alignment System	FTT	Fast Tip-Tilt
BC	Beam Combiner	NIR	Near Infrared
BCA	Beam Combining Area	LD	Laser Diode
BCR	Beam Compressor	MOB	Magic Optical Box
CCR	Corner Cube Retroreflector	MRO	Magdalena Ridge Observatory
DL	Delay Line	MROI	MRO Interferometer
DLA	Delay Line Area	OAP	Off Axis Parabola
FT	Fringe Tracker	UT	Unit Telescope

PROTOTYPING

Secondary Fiducial – Quad Cells

Small quad cells will be used as secondary fiducials to look at the shear of the beam as it travels upstream through the beam relay, to the Nasmyth Table. The quad cells will be located starting at the exit of the DL in the BCA, in vacuum cans at the array arm junctions, as well as in front of M4. To improve stability, the design of the quad cells is simple and symmetric with a minimum amount of hardware elements. This approach will result in a small form-factor and simple construction since real-estate and cost is limited.

Figure 11 A photograph of a prototype quad cell assembled in a lab. The quad cells consist of 4 independent space qualified, silicon, 14% efficiency, solar cells. Mounting of the solar cells onto the background circuit board is done precisely in order to achieve accurate centroiding. Conductive copper pads are etched onto the circuit board to which the solar cells are soldered onto. For the 4 independent solar cells, each individual cell is tested to determine their voltage output levels. The 4 cells are matched or calibrated to match the other cells' voltage outputs.



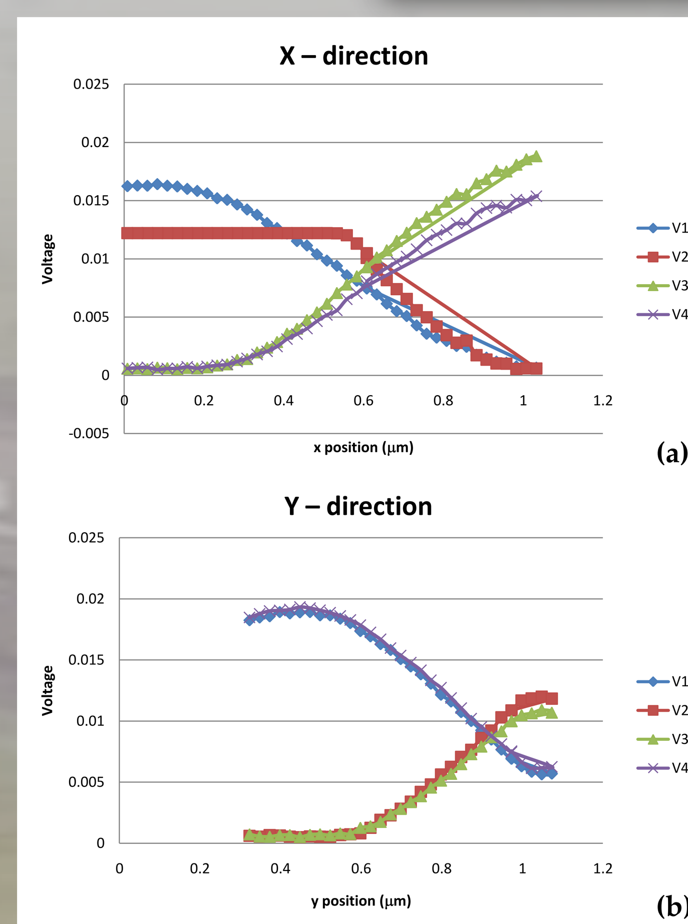


Figure 12 Plots of preliminary test results showing the voltage trend of a laser beam moving across the quad cell in the *x* direction (a) and in the *y* direction (b). The 4 different lines represent each solar cell voltage output. From these initial tests it can be concluded that the solar cells behave similarly, but not exactly the same, therefore in depth characterization of the cells will be necessary so that accurate software calibration can be achieved.

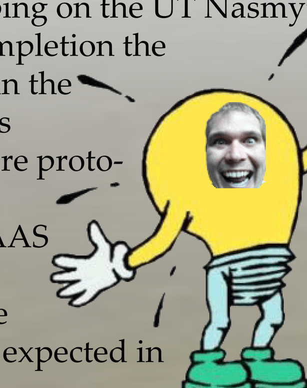
STATUS & FUTURE WORK

Status: The AAS has completed its conceptual design review with great success and is currently in its preliminary design phase. A review/completion is expected in October of 2008. A final design review is schedule for early 2009.

Prototyping: Prototyping the FT AAS set up will commence in mid-July of this year with expected completion by the preliminary design. This includes prototyping and testing all hardware and software necessary to utilize the hardware. The portion of the software that will be completed will include centroiding algorithms, controlling slides, tip/tilt actuation, and flipping mirrors. Centroiding, slide and tip/tilt control software can also be used for the Nasmyth Table and Primary Fiducial table CCDs, slides, and actuators.

Post preliminary design review, prototyping on the UT Nasmyth table components will begin. With its completion the Primary fiducial will then be assembled in the lab. The software portion will continue its development in parallel with the hardware prototyping.

It will be impossible to assemble all the AAS hardware in a laboratory environment, therefore it will be fully assembled on the mountain during its site acceptance tests expected in summer of 2010.



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