Minutes from LBT-OAA Monthly Progress Meeting

Date: April 9, 2010

Location(s): Tucson, Florence, Valmadrera, Bolzano

Participants:
Richard Green, Joar Brynnel, Doug Miller (LBTO)
Simone Esposito, Armando Riccardi, Piero Salinari, Enrico Pinna, Carmelo Arcidiacono, Marco Xompero, Runa Brigulio, Richard Demers (OAA)
Daniele Gallieni (ADS)
Roberto Biasi (MG)

Agenda
Business
Special Topics
Schedule
Status of Action Items
LBTO Vibration study
Open Discussion

1 Business
The date for the next monthly meeting was not set due to the fact that many of the Arcetri personnel will have returned to Mt. Graham by the first week of May. The meeting date/time will be set in late April when activities and daily schedules are more concrete.

2 Special Topics

2.1 Treatment of lost actuators on AdSec_A
For background on the discussion please see the Actuator Failure report in Appendix 1. In this report Armando presented 4 possible options of intervention for short-term repair of the AdSec. The option of not intervening and proceeding with the current plan was also evaluated.

Simone asked if it is possible to fix while AdSec is mounted on the telescope. Armando says this is scary. Richard asked whether everything would be accessible in spider arm configuration.

Richard asked who would do the work. Armando responded that Armando, Guido and Roberto would carry out the work with support from the observatory staff.
Roberto expressed the view that the last option with complete actuator removal and replacement has the highest probability of success while preserving the redundancy of the second capacitive spring contact.

Roberto proposed a 5th option for repair by which an insulating material would be inserted between the contact spring and the cold finger. The advantages: such repair could last a long time while preserving the redundancy of the second capacitive spring contact; clean operation i.e. no solder contamination; this approach is not fully defined yet and must be refined.

Simone pointed out that full replacement of the actuators could be done during the summer shutdown. Simone expressed the concern that replacement of the actuators if it changes the slopes could require complete reacquisition of interaction matrices. Roberto, however, does not expect too much difference in cap sensors.

Rick asked what is the probability of success in recovering 13 actuators with each of the proposed options for intervention? What is the relative probability among the options? Armando responded that in the absence of real-time checkout capability prior to remounting on the swing arm, it is risky to assume recovery of 13 actuators. Option a has no checkout capability whereas the other options offer the immediate opportunity to test the repair prior to reinstallation.

Joar asked whether we would be fixing the symptom or the cause in all of the proposed options? Armando responded by clarifying that the intention is to perform the operation on all the edge actuators not just on the failed edge actuators. This would presumably preempt the possible failure of the remaining functional edge actuators. However, the underlying cause of the failures is thought to be a change relative clocking position between the reference body and the cold plate (actuator supports).

In order to establish further discrimination between options, Rick asked what measures can be taken to avoid solder contamination? Armando responded that there is the standard solder suction in real-time but this provides no guaranty of avoidance of contamination.

Armando stated that Option C-i is perhaps less risky than C-ii because it doesn't involve dismounting actuators. The dismount and remount of actuators is cumbersome and risky. Joar proposed that we settle on one of the Options C-x and allow Roberto decide on the site between C-i and C-ii. There was general support for this but ultimately it was decided to postpone the decision until early the following week when a follow-up discussion would be held including Guido (who did not attend this meeting).

Roberto asked whether he should proceed with exploration of Option C-iii, namely the new option he proposed earlier in the discussion. Armando asked him to proceed until further notice.

Armando proposed to carry out the repair during the first week of May 2010. Simone offered that he could sacrifice some of the time allotted for on-sky alignment with the RRH in order to carry out this operation.

Armando agreed to follow up with a discussion with Guido on the following Monday or Tuesday.
DECISION: begin the repair operation on the wk of 1-9 May; By 10 May the unit must be already remounted with RRH on the DX station.

2.2 Plan for the 2nd commissioning run on Mt. Graham

For background on the discussion please see the FLAO Commissioning report in Appendix 3. In this report Simone summarized the progress in the first commissioning run in Feb-March 2010 and laid out the schedule for the 2nd run in May-June 2010.

Simone requested alignment activity during day in early May. He reasoned that since he is giving up 3 nights in the period 1-3 May for AdSec repair ops it would be beneficial to get 2 half nights in late April for AO alignment prior to the dismount of HUB. In general Simone pointed out that the system alignment is in good shape.

Joar pointed out that Doug says that the focal station commissioning will not be completed by summer shutdown and so more time will be needed in the Fall.

2.3 Status of the 4D interferometer and plans for use

Joar provided an update on the interferometer. It will be ready for use by the end of April with high confidence. Simone said that it will be needed at the first week of May. The new interferometer currently resides on the vendor’s premises for repair. The vendor, 4D, has committed to provide LBT with either the repaired original unit or a loaner by the end of the month.

3 Schedule: FLAO2 Testing at Arcetri

The general schedule for the testing of the second AO system at Arcetri still needs to be replanned in some detail. However, Simone summarized the schedule. The optical acceptance testing of the second AdSec would be completed by the end of the first half of August 2010. Work in the second half of August will be slow due to vacations. The testing of the full AO system would then begin in early September. A conservative estimate is that the AO acceptance testing would be completed by the end of January 2011 and the shipment would be completed by the end of February.

Given that the testing of FLAO2 needs to be re-planned, a general schedule update does not appear in this document. An updated version of the general schedule will be released after some re-planning has occurred. The update will be sent to all on the distribution list of the meeting minutes.

Armando has proposed to carry out a test of the second AdSec with shell mounted at various elevation angles to preempt the sort of problem observed on Mt. Graham with the first unit (shell cannot be flattened at less than 10 degrees elevation above horizon). This test is proposed to be carried out in Italy just prior to shipment to the U.S. Since the test stand has been shipped to Mt. Graham it was decided to borrow the Magellan test stand which currently resides at MG. The precise logistics of this test of LBT672b are undetermined.
4 LBTO Vibrations Study
Jorge has done more modal testing; progress has been made; Jorge has contributed to the development of the accelerometer diagnostic system; The HP is now under investigation. A status report appears in Appendix

5 Open discussion
None
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Appendix 1: OAA Secondary Mirror Actuator Fault Report
During the early usage of the first Adaptive Secondary Mirror unit (LBT672a) at the telescope, we experienced a progressive number of actuators showing faulty behavior. The faulty actuators have been removed from the list of working actuators to allow continuing with AGw acceptance test. The number of removed actuators in the period 6 March – 6 April is 21 (in addition to the already known 19 not working actuators from the Arcetri acceptance test).

The faults can be summarized in three classes:

1) Jumping of capacitive sensor reading of external-ring actuators. The cause has been addressed to the shorting of one of the two (redundant) elastic contacts with the actuator body (grounded). The most probable cause of the problem is an increase of the clocking error between the cold-plate (actuator support) and the reference-plate compressing the elastic contact toward the actuator body by the reference-plate. A collection of 13 actuators can be associated to this problem;

2) A localized area of about 10 actuators show a jump in the capacitive sensor reading producing a smooth bump of about 60um around them requiring to remove 3 edge actuators from the working actuator list. The event was detected for the first time after the mirror cover removal after the telescope installation of the unit (19 Mar). The bump should not be related to dust contamination because its geometry is highly correlated to electronics parts (a signal distribution board). This bump avoids to properly flatten the shell and happened few times in the last month with duration ranging typically from 0.5 to 3 hours (only in one case on 19 Mar the duration was the entire night). The electrical source of this problem is not yet understood.

3) A collection of 5 actuators showing excessive capacitive sensor drift or noise. The source of this problems is not yet understood from an electro-mechanical point of view and, unfortunately, no long analysis time has been dedicated to it in order to not stop the AGw commissioning momentum.

In spite of the number of de-activated actuators, the neighboring actuators allow to apply the flattening command for the mirror without limiting the seeing limited performances experiencing good PSF shapes down to 0.4 arcsec.

Unlike seeing limited mode, the collection of lost actuators could limit the performances of the Adaptive Optics mode, especially when high order correction is performed. That because we have clustered missing actuators at least in 3 spots at the external edge of the shell with very reduced control of the local shape and consequent saturation of wave-front sensor signals and difficult calibration of mirror-sensor response.

A short-term fix should be focused on the solution of the external actuator problem (larger part of faulty actuators, 13 on 21) moving a long-term solution during the summer stop.

We have the following short-term options:

1) Do nothing and accepting the risk to sensitively reduce the AO robustness and performances; any fix of the unit will be performed during the summer stop. That solution is very risky for the success of the AO run;

2) Do some form of fix before the on-sky AO run:
a. dismount the unit from the spider-arm and move the unit close to the dome floor holding it with the crane. Open the lower-end of the shroud and remove the miniskirt to access the external ring of actuators. Detach the shorting elastic contact of external actuators and pre-load the remaining one to assure stable contact without extracting the actuators. The shell cannot be removed at the end of this process without the possibility of cleaning the gap in case of contamination through the reference plate holes occurred during the operations. The result can be tested only after remounting the unit and reconnecting the cabinet electronics. Estimated time: 1day (max 2days moving the test of the result in the second day to free the chamber for night observation).

b. same as before, but moving the unit in the clean room and using the clean room crane. The clean room has the correct power and cooling interfaces for using the spare cabinet electronic parts to test the unit before remounting it on the telescope. Estimated time: 2-3days.

c. move the LBT672a unit in clean room and install the unit on its stand under the clean tent. In case the dismounting can be done with deployed swing-arm, the rotation of the hub could be avoided. Two alternative operations could be done in this configuration:
   i. remove the miniskirt and detach the shorting elastic contact of external actuators and pre-load the remaining one to assure stable contact without extracting the actuators. Lower 10cm the shell for cleaning residuals (dust, particles, ...) felt inside the reference plate holes. Remount the shell and test the unit with spare parts of the swing-arm cabinet at different elevation angles. Remounting the unit at the telescope. Estimated time: 5-6days
   ii. remove the miniskirt and the shell. remove the external ring of actuators and modify them to match the modifications made to the B unit (shortening and reshaping the elastic contacts). Clean, remount the shell and test the unit with spare parts of the swing-arm cabinet at different elevation angles. Remounting the unit at the telescope. Estimated time: 7-8days

The best compromise between safety and results are, in my opinion, “b.” and “c.i.”

The above short-term fix solve temporarily the problem modifying the actuators elastic contact without solving the real source of the problem, i.e. the possible increase of the clocking between cold-plate and reference-plate. A long-term solution should be investigated and possibly applied during the next summer stop.

The best time window for running the actuator fix is before the first extensive AO night run (with some contingency). We propose the days starting on 4th May.

Appendix A: the elastic contact shorting
During the re-installation and functionality checks of the LBT672a that Microgate and Arcetri run in the telescope clean room [RD1] to setup the unit for the telescope installation, we found a critical problem for the external ring of actuators. The clocking error between the cold plate (actuator support) and the reference plate caused one of the two elastic contact used to pick-up the capacitive sensor signal was in short with the actuator aluminum body. In the following pictures it is evident the effect of the decentering on the actuator position and the deformation of elastic contacts.
The issue of relative rotation between cold plate and reference plate was already addressed in the past and actions were taken to solve the problem (see [RD2], [RD3] and [RD4]). Possibly the shipment handling and vibrations showed the shorting problem in phase of re-integration.
Appendix B: list of not working actuators

Here is the map of not working actuators. Green dots: acts lost before Arcetri acceptance. Black dots: acts removed during the last month.

Note that most of the faulty actuators found during last month (black spots) are located on the lower half of mirror edge (gravity direction when horizon pointing), corresponding to the area where the decentering problem due to clocking is more evident.

Here is a list of faulty actuators with the identification of class of problem:

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<td>Large current drift. Could be restored after more accurate investigations.</td>
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<td>595</td>
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<td>671</td>
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Related documents
[RD2] MG_Report_09_10_2007, LBT AO progress meeting
[RD3] MG_Report_08_11_2007, LBT AO progress meeting
[RD5] J. Hill’s mail on 05/Apr/2010
Appendix

Appendix 2: Adaptive Secondary/HUB collision test report
Adaptive Secondary/HUB collision test report

Prepared by
Richard Demers, Armando Riccardi, Marco Xompero, Runa Brigulio

Approved by
Joar Brynnel

Released by
ABSTRACT

Results of the test of the modified telescope HUB are presented.
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## Abbreviations, acronyms and symbols

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1 Summary

This document presents the preliminary results of the telescope hub (HUB) anti-collision test and summarizes the final measures taken in order for the first unit Adaptive secondary mirror (AdSec) to meet the collision avoidance requirement. The test was carried out on ADS premises on 11 and 12 January 2010. As a result of the test four types of collisions were identified which required further modification of the already modified HUB. All of these modifications are minor and were carried out on ADS premises.

The four types of collisions identified by the tests were

a) Collision between the elbow cooling fitting on one of the electronic crates and the internal HUB skin
b) Collision between the two top corner edges of the electronic box facing the swing arm cabinet and the facing internal ribs of the HUB
c) Collision between a handle of one of the electronic board frames on an electronic crate and an internal rib of the HUB
d) Collision between the ribbon cable connector hooks on the second ring of connectors (from the outside) and the bottom surface of the bottom flange of the HUB

These four types of collisions will be avoided and/or mitigated by the following final modifications of the hardware:

a) The dampening springs located on the mounts of the electronic box will compress/extend upon contact between the elbow fitting and the HUB inner skin. The compression/extension of the dampening springs will thereby prevent damage to the elbow fittings. The springs will allow a maximum of 1 cm displacement of the electronic box as measured during the HUB final test. This is enough displacement to compensate for the worst-case HP extension relevant to this collision. No further modification results from this class of collision.
b) The ribs were machined to a narrower depth in the vicinity of the box-corner collision.
c) The internal ribs were machined in the vicinity of the board handle collision.
d) The ribbon cable connector hooks on the second ring from the outside were machined to reduce their height by an amount between 5 and 6 mm, enough to avoid collision with the HUB flange.

The above modifications, resulting from the HUB collision test of January 2010, are documented and specified in an ADS fabrication drawings [7][8].

Finally, the conclusions of the verification of compliance of the two systems is contained in section 6.3.3.

2 Background

2.1 Previous work

A MatLab analysis tool was previously developed[1] in support of the re-design of the RRH G-ring in the solar tower. A requirement for the G-ring re-design was the avoidance of collisions in the solar tower tests. The MatLab tool was modified in order to investigate possible collisions between...
the AdSec and the HUB. For this upgrade of the analysis tool the geometric model of the AdSec had to be refined in four ways: i) improved dimensional accuracy of the AdSec model, ii) completion of the upper and lower parts of the AdSec model, iii) non-axially symmetric features were added to the AdSec model, iv) the outer skin of the HUB was added to the model. These refinements were driven by the differences in dimensions between the telescope HUB and the dummy hub. The larger overall height of the HUB with respect to the solar tower dummy hub and the narrower radius of the HUB both result in closer proximity of the HUB to the AdSec. The dummy hub interior geometry was replaced with the HUB interior and exterior geometry. In addition the tool was upgraded to enable configurations in various HP leg failure modes and the prediction of both vertical and horizontal virtual penetrations due to collisions in 3D space.

The refinement of the AdSec geometrical model was based on the solid model[4] and mechanical drawing files[5],[6] provided by ADS, measurements of the AdSec B-unit, A-unit and the first as-built HUB, and a number of close-up photographs of the AdSec B-unit, A-unit and the first HUB. Some ellipticity and possible vertical tilt was measured in the as-built HUB.

The analysis results, mechanical measurements and photographs were used to prescribe modifications to the as-built HUB. The proposed modifications to the HUB were documented[2] and shortly thereafter, minor revisions were released in an updated version of the document[3].

2.2 Hexapod (HP) safety limits

The HP legs are operated with two layers of extension/retraction safety limits. The first layer consists of the firmware limits (+/- 10mm relative to the zero or “home” position). The second layer consists of the internal electronic switches (approximately +/- 10.3 mm relative to home). The electronic switches are normally xyz and switch to the -xyz state when the leg limit is reached. In the unlikely event of a failure of both the firmware and electronic switches the leg extension/retraction is ultimately constrained by the internal mechanical stops (approximately +/- 12.0 mm). The precise values of the electronic and mechanical limits for each leg of HP-1 appear in Appendix A of this document.

3 Collision avoidance requirement for telescope operations

There will be no collision of the secondary mirror unit and its HUB either i) under normal operating conditions OR ii) in the event of a single point failure of the HP. The single point failure of the HP is defined as a state in which one leg at a time is either fully extended or fully retracted beyond its software limit and reaching its ultimate mechanical limit. There are thus two possible failure modes for each leg and a total of twelve possible single point failure modes of the entire HP.

4 Test objective

The objective of the test was essentially to provide verification of the HUB design modifications. A rigorous test to verify the HUB design compliance with the collision avoidance requirement would have required the disabling of the internal electronic limit switches of the HP legs in order to test HP single point failure modes. However this was considered to be cumbersome and incurring hardware safety risks. Consequently, in the test, the HP legs were always constrained by the firmware limits. In order to verify that the design was compliant even in cases of single HP leg...
extensions/retractions to the mechanical limits, the MatLab analysis tool was used to trace the clearance measurement from the configuration with firmware limits to the one with a single leg reaching its mechanical limit. However, as a result of the test, all of the design modifications of the HUB were directly verified to avoid collisions in normal operation of the HP (but not in a HP failure mode).

5 Test Procedure

The test procedure consisted of verifying clearances between the AdSec and the HUB in each one of 21 worst-case configurations of the HP. The analysis tool was used to predict the difference between the clearances when HP legs are at firmware limits and the clearance at the mechanical limit (for one leg only). The clearances measured in the test were compared with the reduction in clearance that would occur if one of the HP legs reached it mechanical limit.

Clearances were measured either with a digital caliper or using calibrated shim stock. Digital images were taken of each clearance measurement to record visually both the mechanical parts whose clearance was measured and the numerical measurement itself. In some cases where the clearances involved “soft” materials such as electrical cables or optical fibers, the soft objects were tested for the amount of possible displacement.

In preparation for the test, the MatLab analysis tool[1] was used to predict the clearances between the AdSec and the HUB for each of the worst-case positions of the HP. The worst-case configurations consist of all the possible combinations of maximum and minimum HP leg extensions/retractions based on firmware limits. There are 64 such configurations. The MatLab tool was also used to create a list of the 64 sets of HP coordinates (in the telescope coordinate system) corresponding to the 64 worst-case configurations. In addition the tool yielded the minimum clearance for each configuration. An Excel spreadsheet was used to convert the 64 HP positions from telescope coordinates to leg lengths and HP coordinates. The configurations in HP coordinates were then used to generate commands sent to the HP. The list of the 64 HP position coordinates in both coordinate systems appears in Appendix B.

The 64 HP configurations were then sorted in order of increasing minimum clearance as predicted by the tool. A subset of the 64 configurations was selected for the test on the basis of severity. The test was designed to verify the HUB modifications for the specific list of AdSec collisions identified by both analysis and visual inspections. Many of the HP configurations were redundant in that the position of the HP was along the same direction as other more severe configurations. These redundant configurations would essentially be verifying the same “anti-collisions” at larger clearances than the more severe configurations. These redundant configurations were therefore culled from the 64. Other configurations were removed from the test plan by arguments of symmetry. The HP has six-fold symmetry and the AdSec has two-fold symmetry with respect to several of the “anti-collisions”. Consequently some HP configurations would repeat the identical “anti-collision” verification of their symmetric partners. Finally, there were a number of configurations where the minimum predicted clearances were large enough that the risk was assessed to be small enough to ignore. These were also removed.

After removing all repetitious and redundant configurations, there were 21 remaining. For each of the 21 cases the HP was commanded to travel from the initial zero position (thin shell vertex at

INAF – Osservatorio Astrofisico di Arcetri
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http://adopt.arcetri.astro.it

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0,0,0) to the worst-case position in four separate steps. After each step the unit/HUB system was inspected for potential collisions (anticipated by analysis or otherwise) before proceeding to the next step. All possibilities for collisions were already well understood and characterized by extensive use of the analysis tool and investigation of the designs and photographs of the units.

6 Test results

The HUB collision test was carried out in January 2010 in the ADS laboratory using the HUB_A unit and the AdSec_B unit. The AdSec and HP were mounted in the HUB using the interfaces that will be used at the telescope. The entire unit was supported in horizontal orientation from below using a trolley built by ADS. The support points were the four swing arm interface pads. The mechanical configuration of the HUB/AdSec/HP system was identical to that of the telescope in horizon pointing except that the HUB cover plates and AdSec shroud were absent.

The list of potential collision-risks originally identified by the analysis tool appear in Table 1 along with HUB clearances predicted by the tool. All of the risks listed were believed to be avoided by the first round of HUB re-machining that had occurred prior to the test and the clearances associated with each item were verified in the relevant HP configuration cases. A summary of the results of the collision test is captured in Table 2.

Table 1. Collision risks identified using the analysis tool, inspections and photographs

<table>
<thead>
<tr>
<th>AdSec subcomponent</th>
<th>Clearance type</th>
<th>HUB Inner Radius [mm]</th>
<th>Clearance [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronic box corners, top</td>
<td>horizontal with HUB rib</td>
<td>404</td>
<td>&gt;9</td>
</tr>
<tr>
<td>Cooling fittings on elec. Boxes</td>
<td>horizontal with HUB rib</td>
<td>423</td>
<td>6</td>
</tr>
<tr>
<td>Accelerometers</td>
<td>horizontal with HUB flange</td>
<td>415</td>
<td>NA</td>
</tr>
<tr>
<td>Astatic lever</td>
<td>horizontal with HUB flange</td>
<td>423</td>
<td>&gt;14</td>
</tr>
<tr>
<td></td>
<td>horizontal with HUB rib(2)</td>
<td>415</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Hooks on wide ribbon cable connectors, outer ring</td>
<td>vertical with G-ring top flange</td>
<td>N/A</td>
<td>&gt;3</td>
</tr>
<tr>
<td>Narrow ribbon cables (at bend)</td>
<td>vertical with G-ring top flange</td>
<td>N/A</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Electronic connector on box side</td>
<td>horizontal with HUB rib</td>
<td>423</td>
<td>&gt;25</td>
</tr>
<tr>
<td>Fiber connectors on box left side</td>
<td>horizontal with HUB rib</td>
<td>404</td>
<td>~5</td>
</tr>
</tbody>
</table>

6.1 Verification of the previously implemented HUB modifications

The 21 tested HP configurations enabled solid verification that the HUB modifications implemented prior to the test were successful in providing adequate clearance to avoid collisions. Specifically, there was adequate clearance around the a-static levers, the accelerometers, the optical fiber connectors on the crates, the electronic connectors on the crates and all but two of the coolant elbow fittings on the crates. Some ribbon cable bundles emerging from the crates were also a concern. These bundles were in the worst case compressed a bit but not enough to cause damage. Photographic images of these clearances are shown in Figures xx-zz.
6.2 Collisions or near collisions

In the course of running the test a few types of collisions or near collisions were observed. Some of these required further modifications of the HUB. These cases are described in the following sections.

6.2.1 Crate elbow fitting against the HUB skin (Figure xx)

In two of the HP configurations tested the left side elbow fitting (for electronics cooling) on the electronic box located at the right side of the Adsec with respect to the swing arm (at horizon pointing) was observed to either be in collision or near collision with the HUB skin on the swing arm interface side. The location is designated number 4 as shown in the schematic of Figure xyz. The clearance between the elbow and the HUB skin in both configurations was measured to be 2.9mm. When the crate was displaced as much as possible by flexing the mounting flexures the clearance increased to 7.7mm, which is enough to avoid collision in the case of single point failure.

6.2.2 Top corner of electronic box against HUB rib (Figure yy)

In a single configuration tested the top left corner of the electronic box located at the right side of the Adsec with respect to the swing arm (at horizon pointing) was observed to collide with a rib of the HUB. A clearance of 0.5mm was measured when the box mounting flexures were at maximum displacement. To avoid this collision it was decided to remove more of the ribs such that the section of ribs with inner radius of 404mm extends to a greater height above the bottom flange.

6.2.3 Electronic board handle against HUB rib (Figure zz)

In the same configuration discussed in 6.2.2 a near collision was observed between the handle of one of the electronic board frames in the electronic box and a HUB rib. The particular electronic box was the one located at the left side of the AdSec with respect to the swing arm (at horizon pointing). The location is designated number 3 in the schematic of Figure xyz. Although a clearance of 1.7mm was measured between the frame handle and the rib, it was likely that a collision would occur in a single point HP failure mode. In order to avoid this collision the board frame handle was modified to have a smaller profile.

6.2.4 Ribbon cable connector hooks against the bottom flange of the HUB (Figure aa)

In several of the HP configurations tested the top of the hooks of the ribbon cable connectors were observed to collide or nearly collide with the bottom surface of the HUB bottom flange. Only hooks from the second ring of connectors from the outside were at risk. All other connectors were far from collision. Clearances were measured in every observed case of a collision or near collision. All measurements appear in Table 2. The smallest measured clearance was 0.7mm. To avoid damage to the connectors from such collisions the hooks of all the connectors in the second ring were machined such that the height of the hooks was reduced by 6mm. This is believed to result in adequate clearance with respect to the HUB flange based on the predictions of the analysis.

6.3 Traceability of the test to the two AdSec/HUB units

The collision test configuration (AdSec_B mounted in HUB_1) must be traced to the two configurations that will be “flown” at the observatory (AdSec_A in HUB_A and AdSec_B in
HUB (B). The traceability is separated into two parts: i) differences between the two HUBS and ii) differences between the two AdSec units.

6.3.1 Differences between the HUBS

ADS has certified in writing[9] that the inner radii of the HUBs are identical for all parts and locations that were machined specifically[7][8] to avoid collisions. These modifications were carried out in two steps. The first modification[7] was carried out, as mentioned above, prior to the test. The second modification[8] was carried out after the test in order to implement the changes outlined in section 6.2.2 above. We can conclude from this that the inner radii of the ribs are the same in the two HUBs. The inner radii of the skins of the two HUBs, are guaranteed to be the same in all sectors that were machined per the above referenced reworks. This includes the skin at the swing arm interface where a collision was observed between the elbow cooling fitting and the HUB skin.

6.3.2 Differences between the AdSec units

Based on several inspections and two collision tests the two AdSec units are believed to be nearly identical in all dimensions relevant to HUB clearances. There are some known differences between the two units on the top area directly underneath the HP—an area which cannot possibly have a mechanical interference with the HUB. There are also differences in precise paths of soft components such as cooling flex hose, optical fiber, ribbon cable bundles and electrical cables. But the test provided verification that the safe range of motion of these soft components is adequate to avoid any damage. To provide some idea of the level of conservatism used in the HUB re-design, it was found that the dimensions of the "mouse hole" are so large that there was room for many mm of differences in location of the flex tubing. Moreover, in one of the worst HP configurations for the cooling hoses, the flex hoses were manually displaced with finger pressure at least 10mm of displacement without damage.

6.3.3 Conclusions

6.3.3.1 AdSec_2 in HUB_2

Given that the two HUBs are certified[9] based on inspection to be identical and given that AdSec_2 was successfully tested for collisions in HUB_1, it can be concluded that the configuration of AdSec_2 in HUB_2 is in compliance with the anti-collision requirement.

6.3.3.2 AdSec_1 in HUB_1

The compliance of the other configuration (AdSec_1 in HUB_1) rests solely on the dimensional differences between the two AdSec units, which has not been directly verified. However, the probability of a collision in the second configuration due to dimensional differences between the two units is deemed low enough that the residual risk of non-compliance is acceptably low. At the time of review of this document an abbreviated HUB collision test of AdSec_1 in HUB_1 at the LBT Observatory is under consideration. Such a test, if successful, would lay to rest the residual risk of non-compliance of this “flight” configuration. However, such a test is not deemed absolutely necessary.
Figure 0: Schematic of the AdSec-HUB system in telescope against telescope coordinate system[10]. The lines represent the three electronic boxes and the numbers are location references.
Table 2. Summary of significant results of the HUB collision test.

<table>
<thead>
<tr>
<th>Case N.</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>NOTES</th>
<th>Min. Meas. Clearance</th>
<th>Clearance objects description</th>
<th>Clearance objects location</th>
</tr>
</thead>
<tbody>
<tr>
<td>09</td>
<td>-1.66</td>
<td>2.8738</td>
<td>-0.9416</td>
<td>-23.3</td>
<td>-13.452</td>
<td>5.1660</td>
<td>no problem</td>
<td>1.95mm, 1.95, 3.1, 3.7, 0.25, 0.15 Ribbon cable hook/HUB flange;</td>
<td>Box elbow fitting/HUB skin at SW arm; HUB arm mouse hole, -y direction, x=0, SW arm interface side</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>3.3176</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>26.9043</td>
<td>5.1660</td>
<td>Ribbon cable hooks near collision with HUB flange</td>
<td>2.85mm</td>
<td>Ribbon cable hook/HUB flange;</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>-2.753</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-42.68</td>
<td>5.2575</td>
<td>The mousehole size is adequate</td>
<td>1.95mm, 2.85mm</td>
<td>The mousehole size is adequate;</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>1.3772</td>
<td>2.3839</td>
<td>0.0267</td>
<td>-36.962</td>
<td>21.3402</td>
<td>5.2575</td>
<td>The mousehole size is adequate</td>
<td>0.9mm</td>
<td>The mousehole size is adequate;</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1.3772</td>
<td>-2.3839</td>
<td>-0.0267</td>
<td>36.962</td>
<td>21.3402</td>
<td>5.2575</td>
<td>The crate fitting will not be damaged since the crate flexures have adequate displacement</td>
<td>2.85mm, 7.7mm</td>
<td>The crate fitting will not be damaged since the crate flexures have adequate displacement</td>
<td></td>
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<tr>
<td>57</td>
<td>-0.624</td>
<td>3.4474</td>
<td>-1.1937</td>
<td>-39.549</td>
<td>0.0632</td>
<td>1.1716</td>
<td>ribbon cables touched hub</td>
<td>0.885mm</td>
<td>Ribbon cable/HUB flange; negative x direction</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>-2.974</td>
<td>1.744</td>
<td>1.1477</td>
<td>-19.72</td>
<td>-34.282</td>
<td>1.1716</td>
<td>no problem</td>
<td>0.7mm</td>
<td>Ribbon cable hook/HUB flange;</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>-2.974</td>
<td>-1.1477</td>
<td>-1.744</td>
<td>29.7197</td>
<td>-36.282</td>
<td>1.1716</td>
<td>no problem</td>
<td>0.9mm</td>
<td>Ribbon cable hook/HUB flange;</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>2.0986</td>
<td>1.7019</td>
<td>1.2376</td>
<td>-19.829</td>
<td>34.2186</td>
<td>1.1716</td>
<td>no problem</td>
<td>1.3mm</td>
<td>Ribbon cable hook/HUB flange;</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>2.0986</td>
<td>-1.7019</td>
<td>-1.2376</td>
<td>19.829</td>
<td>34.2186</td>
<td>1.1716</td>
<td>no problem</td>
<td>1.35mm</td>
<td>Ribbon cable hook/HUB flange;</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-0.624</td>
<td>-3.4474</td>
<td>1.1937</td>
<td>39.5487</td>
<td>0.0632</td>
<td>1.1716</td>
<td>no problem</td>
<td>0.88mm</td>
<td>Ribbon cable hook/HUB flange; positive x direction, y=0;</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>-1.333</td>
<td>2.3072</td>
<td>-0.2668</td>
<td>-36.646</td>
<td>-21.157</td>
<td>-3.0418</td>
<td>large clearance everywhere; bundle of flat cables inside squeezed a bit but no damage anticipated</td>
<td>2.17mm</td>
<td>Large clearance everywhere; bundle of flat cables inside squeezed a bit but no damage anticipated</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>2.6643</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>42.3149</td>
<td>-3.0418</td>
<td>clearance everywhere, accel a bit close to flange</td>
<td>1.95mm</td>
<td>Clearance everywhere, accel a bit close to flange;</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>1.0254</td>
<td>0.706</td>
<td>-1.1858</td>
<td>-17.586</td>
<td>29.1853</td>
<td>0.9387</td>
<td>no problem</td>
<td>0.8580</td>
<td>No measurement taken</td>
<td></td>
</tr>
<tr>
<td>26</td>
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<td>1.241</td>
<td>1.1931</td>
<td>-24.045</td>
<td>0.9387</td>
<td>0.8580</td>
<td>no problem</td>
<td>0.9387</td>
<td>No measurement taken</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>-1.124</td>
<td>0.5349</td>
<td>-1.1973</td>
<td>-16.459</td>
<td>-29.099</td>
<td>0.9387</td>
<td>box fitting n.4 collided with rib &lt;0.5mm clearance when fl x pushed;</td>
<td>1.65mm</td>
<td>Box fitting n.4 collided with rib &lt;0.5mm clearance when fl x pushed;</td>
<td>negative y direction</td>
</tr>
<tr>
<td>23</td>
<td>1.0254</td>
<td>-0.705</td>
<td>1.1856</td>
<td>37.5861</td>
<td>29.1853</td>
<td>0.9387</td>
<td>no problem</td>
<td>1.65mm</td>
<td>Box fitting n.4 collided with rib &lt;0.5mm clearance when fl x pushed;</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>1.7661</td>
<td>6.6233</td>
<td>2.3944</td>
<td>-17.734</td>
<td>13.5429</td>
<td>-3.4945</td>
<td>no problem</td>
<td>8.8234</td>
<td>No measurement taken</td>
<td></td>
</tr>
<tr>
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<td>-1.7918</td>
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<td>20.9993</td>
<td>8.8663</td>
<td>-3.4945</td>
<td>no problem</td>
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<td>No measurement taken</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.0247</td>
<td>-1.7506</td>
<td>-1.1801</td>
<td>39.8258</td>
<td>7.9256</td>
<td>8.8234</td>
<td>no problem</td>
<td>8.8234</td>
<td>No measurement taken</td>
<td></td>
</tr>
<tr>
<td>33</td>
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<td>-1.2093</td>
<td>-3.1285</td>
<td>21.086</td>
<td>8.8234</td>
<td>no problem</td>
<td>8.8234</td>
<td>No measurement taken</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>1.2253</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>25.304</td>
<td>-1.1557</td>
<td>no problem</td>
<td>25.304</td>
<td>No measurement taken</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1: Horizontal configuration of AdSec_1 mounted in HUB_1 for the collision test. The HUB is supported from below at the swing arm interfaces by the custom trolley.
Figure 2: Collision a. between the elbow fitting on the electronic box facing the swing arm cabinet and the HUB skin (location 4 of Fig 0). The elbow fitting is seen at the center of the left image. Immediately below the fitting is the flat plate portion of the HUB skin located at the swing arm interface. A calibrated shim is fit tightly below the fitting measuring the clearance (result, 2.85mm, shown in right image). HP test configuration no.7.

Figure 3: Collision b. between top corner of the electronic box closest to the swing arm interface and the HUB internal rib.
Figure 4: Collision c. between the electronic board chassis handle on the electronic box nearest the swing arm and an internal rib of the HUB. Location 3 of Fig 0.

Figure 5: Collision d. between the ribbon cable connector hooks (second ring from outside) and the bottom flange of the HUB. HP test configuration no. 7.
Figure 6: Collision between the ribbon cable connector hooks (second ring from outside) and the bottom flange of the HUB to the immediate left of swing arm mouse hole. HP test configuration no.50.

Figure 7: Left: a view of the mouse hole on the opposite side of the swing arm (+ y direction, Fig 0) in a HP configuration near zero position. Right: a view of the same mouse hole when HP is in a worst case position. HP test configuration no.25.
Figure 8: Left: a view of the lower right side of the mouse hole on the opposite side of the swing arm (+ y direction) in the same HP configuration as Figure 7. Right: a view of the same mouse hole at right top showing adequate clearance for flex hose. HP test configuration no.25.

Figure 9: Left: a view of the top of the mouse hole on the side of the swing arm (- y direction, Fig 0) in a configuration placing the coolant hoses as far as possible against the HUB mouse hole. Hoses are just touching the HUB with very little force. Right: a view of the mouse hole top in the same configuration showing additional clearance for flex hoses when forcibly displaced without danger of damage. HP test configuration no.34.
Figure 10: Two views of the optical fiber connectors emerging from the box that is oriented parallel to the x-axis confirming that the HUB rib modification avoids collisions with the fiber connectors. Left: a view from the right side of the rib. Right: a view from the left side of the same rib. HP test configuration no.25.

Figure 11: Views of the ribbon cable connector hooks before (left) and after (right) the removal of material from the hooks as a collision prevention measure. The height of the hooks was reduced by 6mm.
7 Appendix A: Hexapod leg length parameters

These are the mechanical limits of the HP legs

\[
\begin{align*}
\text{specL1max} &= (11.5e-3+dL1max); & \text{\% leg length positive range} \\
\text{specL1min} &= -(12e-3+dL1min); & \text{\% leg length negative range} \\
\text{specL2max} &= (11.5e-3+dL2max); \\
\text{specL2min} &= -(12e-3+dL2min); \\
\text{specL3max} &= (11.5e-3+dL3max); \\
\text{specL3min} &= -(12e-3+dL3min); \\
\text{specL4max} &= (11.5e-3+dL4max); \\
\text{specL4min} &= -(12e-3+dL4min); \\
\text{specL5max} &= (11.5e-3+dL5max); \\
\text{specL5min} &= -(12e-3+dL5min); \\
\text{specL6max} &= (11.5e-3+dL6max); \\
\text{specL6min} &= -(12e-3+dL6min); \\
\end{align*}
\]

These are the electronic limits of the HP legs

\[
\begin{align*}
\text{specL1max} &= (10.33e-3+dL1max); & \text{\% leg len positive range} \\
\text{specL1min} &= -(10.803e-3+dL1min); & \text{\% leg len negative range} \\
\text{specL2max} &= (10.480e-3+dL2max); \\
\text{specL2min} &= -(10.847e-3+dL2min); \\
\text{specL3max} &= (10.648e-3+dL3max); \\
\text{specL3min} &= -(10.532e-3+dL3min); \\
\text{specL4max} &= (10.854e-3+dL4max); \\
\text{specL4min} &= -(10.881e-3+dL4min); \\
\text{specL5max} &= (10.658e-3+dL5max); \\
\text{specL5min} &= -(10.408e-3+dL5min); \\
\text{specL6max} &= (10.281e-3+dL6max); \\
\text{specL6min} &= -(10.835e-3+dL6min); \\
\end{align*}
\]

These are the firmware limits of the HP legs

\[
\begin{align*}
\text{specL1max} &= (10.00e-3+dL1max); & \text{\% leg len positive range} \\
\text{specL1min} &= -(10.00e-3+dL1min); & \text{\% leg len negative range} \\
\text{specL2max} &= (10.00e-3+dL2max); \\
\text{specL2min} &= -(10.00e-3+dL2min); \\
\text{specL3max} &= (10.00e-3+dL3max); \\
\text{specL3min} &= -(10.00e-3+dL3min); \\
\text{specL4max} &= (10.00e-3+dL4max); \\
\text{specL4min} &= -(10.00e-3+dL4min); \\
\text{specL5max} &= (10.00e-3+dL5max); \\
\text{specL5min} &= -(10.00e-3+dL5min); \\
\text{specL6max} &= (10.00e-3+dL6max); \\
\text{specL6min} &= -(10.00e-3+dL6min); \\
\end{align*}
\]
## Appendix B: Collision test HP coordinates

<table>
<thead>
<tr>
<th>TELESCOPE COORDINATE SYSTEM</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
<th>U1</th>
</tr>
</thead>
<tbody>
<tr>
<td>x m</td>
<td>23.3</td>
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<td>-26.904</td>
<td>0</td>
<td>-23.3</td>
<td>36.962</td>
<td></td>
</tr>
<tr>
<td>y mm</td>
<td>-1.452</td>
<td>5.166</td>
<td>3.318</td>
<td>0</td>
<td>-2.687</td>
<td>2.384</td>
<td></td>
</tr>
<tr>
<td>z m</td>
<td>-1.666</td>
<td>-2.873</td>
<td>0.042</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>a deg</td>
<td>0.01</td>
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<td>0</td>
<td>0</td>
<td>-0</td>
<td>0</td>
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<tr>
<td>b deg</td>
<td>0.01</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0</td>
<td>0</td>
</tr>
<tr>
<td>c deg</td>
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<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0</td>
<td>0</td>
</tr>
<tr>
<td>HEXAPOD COORDINATE SYSTEM</td>
<td>x m</td>
<td>y mm</td>
<td>z mm</td>
<td>a m</td>
<td>b arcsec</td>
<td>c arcsec</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
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<td>-0</td>
<td>0</td>
</tr>
</tbody>
</table>

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Lago E. Fermi, 5 - 50125 Firenze - ITALY

http://adopt.arcetri.astro.it

33
With reference to final dimension to the two LBT M2 hubs, we certify that all the measures are as per drawing 642a373g and 642a382b.

In particular the following internal dimension that are called out in the list below the figures:

Radius 404mm for 308mm
Radius 412mm for 235mm
Radius 423mm for 160mm
Radius 415mm for 15mm
Radius 404mm for 360mm
Radius 419mm for 160mm
Radius 414mm for 308mm
Radius 423mm for 160mm
N.2 Windows 120x90mm (radius 10mm)
TOP VIEW

N.4 holes diameter 9.525mm on 534.6
N.5 holes M6 on radius 515mm
N.2 holes 4H7 on radius 515mm
Moreover, after the re-working we have checked the geometrical tolerance between the interface HP and Spider.

HUB "A" = 0.08mm from lower interface and upper interface (not perpendicularity)
HUB "B" = 0.05mm from lower interface and upper interface (not perpendicularity)

The precision of the all measures are inside the +/- 0.2mm general tolerance specified on the drawing. The accuracy of the measuring machine was 0.05mm.
For what concern the external dimension, we have measured the new interface for the M2 cover and RRH.

See dwg 642a382b
LBT M2 HUB REWORKED DIMENSIONS
10 Appendix D: Design for final modifications of HUB (642a373f)
11 References

[4] CAN 640a004b, solid model of AdSec, prefabrication
[5] CAN 642a241c, design of AdSec
[6] CAN 640a003e, design of AdSec
[7] CAN 642a373g, final HUB modifications resulting from the HUB collision test
[8] CAN 642a382b, HUB rework drawing
[10] LBTO Coordinate System Description, Douglas Miller, CAN 002s105, 22 January 2010
Appendix

Appendix 3: OAA FLAO No.1 Commissioning Run No.1 Activity Report
2 FLAO#1 commissioning activity present status

This is a short resume of the commissioning activity of the FLAO system done in the period February 10th -- March 18th. The commissioning team included about 10 people from the Arcetri Observatory and 2/3 people from ADS and MG. The two main units of the FLAO system, the adaptive secondary mirror and the W unit, have been received at the telescope on time the 2nd and 3rd week of February. The units have been re-integrated and tested in the LBTO optical lab. The test have been done in the period February 15th March 5th. The two units (adaptive secondary & AGW unit) have been installed at the telescope starting from the 6th of March (see slides). The installation has been completed the 8th of March as scheduled. The functional check of the units after installation has been positive apart from some minor issues that will require some further attention. Briefly, the secondary mirror has ten edge actuators that cannot be controlled. The W unit
experienced a few power resets that seems to be related with a loosen connection in the electronic boxes. The 12th of March the IRTC unit has been installed on the RFBG. In the same day the retroreflecting optics has been installed in front of the secondary mirror. The 14th of March the alignment of the complete AO system was started to have an alternative methods to measure a new flat command for the adaptive secondary. The 15th of March the system alignment was completed. The 16th of March the loop was closed to flat the adaptive secondary. The loop was first closed using 20 modes and then using 200 modes. Interestingly the interaction matrices has been measured at the telescope. This activity has provided the flattening command for the mirror that is now successfully used during seeing limited observations. As a last point some images of 0.5 arcsecond FWHM (see slides) have been acquired during the commissioning of the right front focal station using the adaptive secondary in fixed mode. The first commissioning run has been closed the 17th of March. The activities performed up to now have been following the FLAO commissioning schedule presented at the LBT board meeting held the September 14th 2009 in Florence (see Table 1). Briefly the average number of persons for the Arcetri team during this first commissioning run was 7. The maximum number of persons simultaneously present at the telescope during commissioning phase was 10. The two numbers are consistent with what anticipated in the FLAO commissioning plan issued in the FLAO system review of March 2009. The total manpower in this first run was 1.2 FTE. A Twiki page is under construction where all day activity report of the commissioning run #1 are logged. The page will be accessible form the next week.

Table 1 The schedule of the AO system commissioning as presented in the September 14th 2009 LBT board meeting
Table 2: A resume of the man-power required for the FLAO#1 commissioning run as presented at the FLAO review of March 2009.

3 Schedule for the FLAO system commissioning activity from April to June 2010

Below we report a resuming table of the different tasks to be performed in the period April-June 2010 during the commissioning of the FLAO system#1. A short description of each task is reported after the table. The total number of days for daytime activity required for this phase is 27. The total number of nights required in this phase is 18. The total number of days considering that daytime and night time are done always on different days is 45 days.

<table>
<thead>
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<tr>
<td>TASK#1: 28th April - May 1st (4days) AGw#2 commissioning DX (FLAO#1 daytime alignment)</td>
<td>19th – 20th Short test pupil position</td>
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<tr>
<td>April</td>
<td>TASK#3: 10th – 13th (6days). FLAO#1 daytime</td>
<td>TASK#2: 1st May - May 3rd (3nights) AGw#2 commissioning DX (FLAO#1 on-sky 1st alignment)</td>
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<td>May</td>
<td>TASK#6: 6th – 11th (6days). FLAO#1 daytime</td>
<td>TASK#4: 19th – 26th (8days). FLAO#1 daytime</td>
<td>TASK#5 27th – June 3rd (8 nights) FLAO#1 commissioning</td>
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<tr>
<td>June</td>
<td>TASK#7: 18th – 20th (3days). FLAO#1 daytime</td>
<td>TASK#8: 21st – 27th (7Night). FLAO#1 commissioning</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: A resume of commissioning tasks and date in the period April – June 2010
4 AO commissioning activity task description

The tasks to be performed in the period April/June 2010 are described below. The numbering of the task is the same introduced in Table 3.

TASK1) Alignment of the WFS unit with the telescope optical axis identified by the RFBG rotator has to be completed. Some residual misalignment can be corrected in this phase shimming the WFS board (require access to the AGW unit with telescope at horizon).

TASK2) On sky first alignment test of the system. The pupil position during on sky observation is checked to be consistent with the position determined during day time alignment. Effect of pupil displacement with telescope elevation is measured. A check of the operation of the pupil rotator and the atmospheric dispersion corrector (ADC) is done.

TASK3) System initial calibration and SW verification
   a) FLAO system SW operation (engineering SW, AO supervisor, AOS) full check.
   b) WFS pupil images registration
   c) Modal interaction matrices acquisition
   d) Closed loop test with new IM and IRTC measurements of SR
   e) Measurement of vibration spectrum as seen by the WFS and IRTC

TASK4) System performance verification (phase I)
   a) Measurements of modal IM for the 4 WFS sampling.
   b) Closed loop performance verification (engineering SW)
   c) Closed loop performance verification using observing modes

TASK5) FLAO system on sky test (phase I). The seeing value obtained from the DIMM should be available at this time together with wind speed. These two values are needed to properly configure the AO system during the observations.
   a) baseline: closed loop performance with up to 200 modes will be tested at different elevation angle and with different star magnitudes. The system will be configured using the high level SW and the pre-computed look-up tables. System performance will be measured acquiring long exposure and short exposure images in H band with the IRTC. First investigations of the effect of pupil de-rotation and ADC correction on system performance will be done.
   b) goal: closed loop performance with the maximum available number of modes (496) will be tested as above.

TASK6) System performance verification (phase II)
The task is similar to the task #4. Missing measurements and eventually system registration will be completed and revised. System performance will be measured using IRTC images. The use of Kalman filter, as a vibration mitigation strategy, could be tested at this time.

TASK7) System registration, automatic configuration and performance check before on sky run #2

TASK8) FLAO system on sky test (phase II)

The system closed loop performance will be measured as a function of star magnitude. The system will be operated completely using the AOS GUI. The system performance will be measured by taking long and short exposure in H band using the IRTC camera. All observing modes will be tested at this time namely field stabilization and auto-configuring mode (ACE). The maximum SR achievable and the system limiting magnitude will be determined in this run.

5 Note on AO February-June 2010 commissioning activity:

The commissioning activity done in the period February 8th - March 17th corresponds to the activity showed in the FLAO commissioning schedule (reported in Table 1) under the tasks 1st - 11th. Table 3 is a resume of the main tasks and related dates to be performed in the commissioning period April-June 2010. Yellow marked dates are a request to LBTO and are not at the moment officially assigned to AO commissioning in the present schedule. If assigned the total time for commissioning in between April-June will be:

- Total daytime activity before first AO run on sky (27th May – June 3rd) => 18 days
- Total on sky alignment nights before first AO run on sky (27th May – June 3rd) => 3 nights
- Total daytime activity before second run on sky (21st – 27th June) => 9 days.

Considering the above time allocation we find that the activity planned for the April – May 2010 correspond to the activity showed under the tasks 13th – 17th of the FLAO commissioning schedule. In this case the days assigned to daytime activity are 18. This is consistent with the 15 days planned in the schedule plus 3 more days of alignment. These 3 days were missing from the previous slot. The observing nights number is 8 nights instead that 5. The 3 more nights will be compensated later in the commissioning program.

The activity planned in June 2010 correspond in term of allocated time to about half of the activity showed under the general task 18th. In fact there are 9 days of daytime and 7 nights of observations against 20 day and 17 nights allocated on task 18.
Appendix

Appendix 4: LBT-AO Tucson: M2 Installation Report
LBT PROJECT

2x8,4m TELESCOPE

M2 Unit#1
Telescope Installation Report

<table>
<thead>
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<td>G. Brusa</td>
</tr>
<tr>
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<td>First draft</td>
<td>G. Brusa</td>
</tr>
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3. List Of Abbreviations
4. About this document

4.1. Purpose
This document reports on the activity of the first telescope installation of the M2 Unit#1. It contains notes and issues AIs to be completed at a later time.

4.2. Reference Documents

RD1 “Procedure for M2 installation on the telescope” – ADS Int., March 2nd, 2010
5. M2 Installation

The installation was carried out following procedure [RD1] in two steps. The first step, carried out on March 5th afternoon, consisted in rotating the unit around its axis by 72 degrees to prepare it for installation on the swing arm in the retracted position; the second, carried out on March 6th, installed the unit on its swing arm.

5.1. Hub rotation

This operation was carried out by the following team: G. Brusa (operation manager), J. Little (crane operator), E. Anaclerio (operator 1) and A. Riccardi (operator 2). Richard Sosa and Richard Green took pictures.

5.1.1. Operation Timeline

15:15 brief meeting
16:00 lifting fixture installation
17:00 lifting of hub (M. Andrighettoni replaced A. Riccardi).
17:30 hub rotation completed
17:45 hub lowering
18:00 lifting fixture re-clocking
18:15 Unit clean up

(see Appendix A for some photos).

5.2. Hub installation

This operation was carried out by the following team: G. Brusa (operation manager), J. Little (crane operator), E. Anaclerio (operator 1) and J. Urban (operator 2). Several people from LBTO Mountain day crew supported the operation, Richard Sosa (SO) and people from INAF followed the operation and took pictures.

5.2.1. Operation Timeline

8:00 brief meeting and transportation of M2 from clean room to high bay area
9:00 lifting of M2 from its transport cart
9:30 lifting of M2 thru the hatch to the telescope floor
9:40 beginning positioning M2 with respect to swing arm
9:50 bolting completed
10:20 removal of lifting fixture completed
12:30 cabling and cooling lines hook up.
Lunch break
14:30 cabling and cooling lines hook up completed.
14:50 installation completed with telescope at zenith (and M2 Unit retracted).

(see Appendix B for some photos).

### 5.3. Notes

1. Enzo noticed that the hub holes did not quite match the spider arm ones; it turned out that the spider arm was not fully deployed making the two not matching
2. the Unit was missing the rear cover; a simple Plexiglas cover was made on the spot and fitted later by M. Andrighettoni
3. the mirror cover was not removed.

### 6. M2 Cover Removal and Retro-Reflector installation

The operation was done on March 13\textsuperscript{th} by: J. Urban (operation manager), R. Hansen (operator 1) and A. Riccardi (Operator 2) and K. Newton (?) (crane operator). G. Brusa attended the operation and took pictures. Note that no procedure was available at the time, neither for the cover removal nor for the retro-reflector installation.

#### 6.1. Operation Timeline

Not available.

#### 6.2. Notes on cover removal

1. Because of telescope balancing problems it was decided to perform the operation with M2 Unit in the deployed position, this forced working at higher height and with one operator (A. Riccardi) on one side of the spider arm on the scissor lift and a second one (R. Hansen) on the opposite side on a boom lift.
2. Since the M2 was deployed the guides for the cover were not correctly clocked and the cover could not be simply slid along its guides while holding it up with the crane, as originally designed. Instead the cover was first removed with both teams holding the cover up by hand and the crane simply attached to the central hook of the cover. Once the cover was away from the M2 Unit it was lifting and moved further away using the crane.

#### 6.3. Notes on retro-reflector installation

1. The installation of the three interfaces to the hub showed some difficulties, in particular in the set of two pins used to align the interfaces in the axial direction and rotation. These pins were supposed to be installed before tightening the retaining screws and then removed, however once installed some of them could not be removed. The potential danger of having them fall down was considered
small and of small impact (they weight fraction of grams) however some tape was used to keep them in place.

7. Retro-Reflector removal and M2 Cover installation

The operation was done on March 16th by: J. Little (operation manager and operator 1), A. Riccardi (Operator 2) with the support of D. Officer (scissor lift operator) and K. Newton (?) (crane operator). G. Brusa attended the operation and took pictures. Note that no procedure was available at the time, neither for the retro-reflector removal nor for the cover installation.

7.1. Operation Timeline

13:30 preparation and tool gathering
14:10 crane and lifts positioning
14:15 retro-reflector connected to crane
14:30 retro-reflector on crane
14:45 retro-reflector interfaces removed
15:00 mirror cover installed

7.2. Notes on retro-reflector removal

1. All the pins left in the retro-reflector interfaces were retrieved
2. The unit was weighted for the first time at 20 Kg.

8. List of Issues and AIs

8.1. M2 Installation

1. The current procedure requires rotating the hub before installation. If the installation could be performed with the swing arm in the deployed position, no rotation would be necessary – **AI1: Investigate the possibility of installing the M2 Unit in the deployed position.**
2. **AI2 - Update the current M2 installation procedure (see also AI1).**

8.2. M2 Cover removal/installation

1. The current mirror cover was designed to be installed with the hub in the clocking corresponding to unit retracted – **AI3: Investigate the installation of the mirror cover in the retracted position.**
2. The current mirror cover requires having the hexapod switched off (risk of collision between unit and cover) – **AI4: investigate a mirror cover design that**
will not present a risk of collision (larger diameter) or alternatively a safer lock out mechanism to prevent the collision.  
3. The current mirror cover is not ‘moth-proof’, in other words it is very likely that moths will make their nests inside the cover or potentially anywhere in the volume between the hub and the unit – **AI5: investigate a mirror cover design that provides a seal towards the outside**.  
4. **AI6 – Produce a mirror cover removal/installation procedure (see also AI3).**

### 8.3. Retro-reflector installation/removal

1. The pins used to locate the three interfaces on the hub are making the installation and removal operation overly complicated – **AI7: design a new set of pins that are captive (at the interface?) and have a shorter insertion length (a few mm?)**.  
2. **AI8 – Produce a retro-reflector installation/removal procedure (see also AI7).**

---

1 The scope of the mirror cover should be considered here, if it is determined that the cover is going to be used during installation/ removal only this AI should be cancelled.

2 Notice that there are two issues here: one is the sealing of the volume between the AS unit and hub, the second is the sealing of the volume inside the cover, i.e. between the cover and the shell. While the first issue need to be resolved also when the mirror cover is not installed (see AI issued during the acceptance of M2 Unit#2) the second is pertinent only in case the mirror cover is on for long periods of time, if it is determined that the cover is going to be used during installation/ removal only this AI should be cancelled.
9. Appendix A – M2 Installation part 1 – hub rotation

Figure 1 – 15:15 brief meeting

Figure 2 - 16:00 lifting fixture installation
Figure 3 – 17:00 lifting of hub.

Figure 4 – 17:30 hub rotation completed
Figure 5 - 17:45 hub lowering

Figure 6 - 18:00 lifting fixture re-clocking
Figure 7 - 18:15 Unit clean up
10. **Appendix B M2 Installation part 2 – hub installation**

![Figure 8 - 8:00 brief meeting](image1)

![Figure 9 - 9:00 lifting of M2 from its transport cart](image2)
Figure 10 - 9:30 lifting of M2 thru the hatch to the telescope floor

Figure 11 - 9:40 positioning M2 with respect to swing arm
Figure 12 - 9:50 bolting completed

Figure 13 - 10:20 removal of lifting fixture completed
Figure 14 - 14:30 cabling and cooling lines hook up completed.

Figure 15 - 14:50 installation completed with telescope at zenith (and M2 Unit retracted).
11. Appendix C retro-reflector removal and M2 cover installation

Figure 16 - 13:30 preparation and tool gathering

Figure 17 - 14:10 crane and lifts positioning
Figure 18 - 14:15 retro-reflector connected to crane

Figure 19 - 14:30 retro-reflector on crane
Figure 20 - 14:45 retro-reflector interfaces removed

Figure 21 - 15:00 mirror cover installed
Appendix

Appendix 5: Photographic Report – AGW/LBT672a/FLAO Installation
LBT67 assembly and shell handling

20Feb

22Feb

23Feb

24Feb

27Feb

29Feb

03Mar

04Mar

05Mar
Mounting AGW
Mounting LBT672a
FLAO#1 on LBT DX
FLAO#1 FIRST CLOSED LOOP (16 Mar) at telescope with calib source
LBT672a #1 seeing limited image (0.5arcsec)
Appendix

**Appendix 6: VIBR: Vibration analysis and mitigation (provided by Joar Brynnel)**

**Brief Description**

The VIBR effort seeks to characterize and modify the LBT vibration environment in order to meet optical-path-difference (OPD) and tip-tilt vibration performance requirements.

VIBR vibration characterization efforts include cataloging of vibration sources, direct measurement of LBT optics and structures, optical pointing jitter characterization of the LBT, and (eventually) establishment of processes to assess and correct vibration sources and control measures.

In order to estimate (OPD) performance, an OPD and Vibration Measurement System (OVMS) is currently under development by LBT partners MPIA & LBTI. The OVMS system will provide optical patch difference measurements, as well as raw vibration measurements for characterization of LBT mirrors and structures.

Current VIBR work is focused on vibration characterization and analysis of the left secondary mirror and swing-arm, as well as analytical simulation work. Vibration mitigation planning and action will follow as necessary.

Related VIBR tasks may include structural health monitoring for various off-telescope components (HBS, bogey systems, etc.) and environmental sensing. However, these efforts are secondary to meeting performance related vibration requirements.

**Phase of the Project**

VIBR efforts are currently focused on characterization testing of the OVMS hardware and sensors, as well as on continued analysis data collected using accelerometers currently installed at the SX rigid secondary.

Modeling and simulation of the secondary structure have begun. This effort will include dynamic models adapted from the ADS finite element analysis model as well as dynamic models developed from modal testing of the (SX) secondary swing-arm. Results of the modeling effort will guide vibration mitigation solutions as well as facilitate vibration performance prediction related to evolving LBT and instrument configuration.
Specific objectives that had been set for the period being reported, and for prior periods

1) VIBR primary objective is to finish dynamic characterization of the OVMS accelerometers. This includes quiet-testing as well.
2) Collaboration with LBTI on OVMS cable-testing.
3) Analytical modeling to investigate M2 deployment beams (chrome rods) and to supplement FEA and modal testing.
4) Initiate modal testing of LBT SX secondary swing-arm, followed by modal testing of other swing-arms. (Brush-up on system identification and model reduction.)
5) Initiate FEA analysis using ADS FEA model as a starting point. Become more familiar with ANSYS software.
6) SPIE abstract submitted—covering modeling and modal analysis efforts.
7) Temporary OVMS and UEI DNR data acquisition system software development and deployment.
8) Generation of vibration specification for LBTI and L-N instruments, including initial performance goals for OPD motion (L-N driven) and angular pointing jitter (AO driven), but not necessarily including final method of test and verification.
9) Vibration and pointing jitter analysis during Left Direct Gregorian commissioning. (IRTC FITS block + vibration measurements)

Objectives accomplished in the period being reported / impact and plan to resolve objectives not achieved

1) Dynamic characterization of 33 OVMS accelerometers (out of 45 total) has been completed. Eight accelerometers have yet to be purchased by LBTI. Once acquired, these eight accelerometers and the accelerometers which have been traded off the LBT structure will be characterized. Quiet testing was attempted unsuccessfully; we do not have a quiet-enough location to see the noise floor over the range of interest (10-100-Hz). (75% completed. 100% completion contingent on acquisition of hardware by LBTI partner.)
2) Accelerometer cables to SXM2, SXM3, DXM2, DXM3, SXLBC, and DXLBC have been tested, with one defective cable found. Cable tests included continuity & short tests with realistic ICP load as well as 1-Hz to 12-kHz chirp response. M1 cables, instrument rail cable and “rover accelerometer” cables have not been run yet. (50% complete. 100% complete for installed accelerometers.)
3) Modal testing conducted in March, 2010 indicates that the “chrome rods” are probably not the source of the disturbances seen in Fall 2009. Characterization and modeling of the swing-arms and chrome rods is therefore on hold. (Effort on-hold at 20%.)
4) Modal testing on SX M2 assembly has commenced, with unexpected results. This effort is ongoing, with focus shifting from the chrome guide rods to the SXM2 hexapod and structures in the SXM2 “can.” (Swing-arm characterization effort 25%, with scope expanded to hexapod.)
5) Finite element analysis efforts have not yet commenced due to schedule/time limitations. (0% complete.)

6) SPIE conference abstract accepted, with 20-minute talk scheduled.

7) LabView language based “QuickView” software for the OVMS system has been installed at the LBT site—on the weather computer. The user interface has to be scaled to fit the display in the control room. The installation requires a few additional tweaks, tuning and testing, but is otherwise functional for the currently installed 24 channels. (90% complete, with remaining 10% planned for week 1 April, 2010.)

Similar software for the LBT-owned UEI PPC5 “cube” is on hold.

8) A draft of LBT vibration specifications imposed by LBTI and L-N instruments was completed in December, 2009. It included initial performance goals for OPD motion (L-N driven) and angular pointing jitter (AO driven). Completed, pending feedback.

Note: Specifications do not address *how* performance requirements will be demonstrated or tested.

9) Pointing jitter analysis for several IRTC commissioning efforts in 2008 and 2009 has been completed. Raw data, reduction and plots have been posted to the LBT TWiki page.

In addition, two 30000-frame IRTC image cubes were collected during left direct Gregorian commissioning on 27 October, 2009. Data was collected concurrently with the OVMS system and four accelerometers mounted on the left secondary mirror. Analysis allows for clear visual correlation between IRTC image motion and secondary mirror motion. Data and results have been posted to the LBT TWiki page. Two additional attempts to demonstrate coherence between M2 motion and IRTC images have been thwarted by weather and by commissioning schedule/priorities. Initial efforts completed, and follow-up testing is on-going.

10)(Unscheduled objective, November, 2009-January 2010) OVMS data analysis reveals that over 90% of secondary swing-arm motion in the OPD direction is between 10-Hz and 20-Hz. Examination of ADS technical documents reveals that the motion is likely due to structural modes of the swing-arm’s deployment beams, which have bending modes at about 10-Hz. However, modal testing of the “chrome rods” in March 2010 discounts this theory. Furthermore, the actual chrome-rod preload (100-kN) is not consistent with the ADS analysis (50-kN). Hence this effort is terminated.

11)(Unscheduled objective, January 2010) During accelerometer characterization testing, timing issues were discovered in the OVMS data acquisition system. An A/D conversion rate discrepancy between user-configured rate and the actual rate (~1%) impacts all spectral analysis of data collected with the OVMS system since October, 2009. The hardware vendor (UEI) has indicated that this is expected behavior with the configured hardware. (It is not yet known if it is “documented” behavior.) Preliminary investigation indicates that there is a small impact to completed vibration analysis. However, some existing correlation analysis will have
to be updated—(or otherwise deleted). Update of the correlation analysis is suspended due to time constraints. This effort is on-hold at 90%.

12)(Unscheduled objective, 24 March, 2010) Modal testing of SX M2 structure clearly indicates 12-Hz and 14-Hz structural modes. This behavior must be understood in the context of M2 tip-tilt and OPD, especially since it occurs in the band of interest—the 10-20-Hz band where most of the M2 noise is located. Damping should be analyzed and possible damping options explored. (This effort is new, and replaces the chrome-rod characterization efforts: 20%).
Objectives for the current period

1) (Immediate) Test and tuning of OVMS quick‐look software at LBT
2) (Immediate) Modal testing of SX M2 hexapod and “can” structure as follow‐up to inconclusive tests on swing‐arm and chrome‐rods
3) (Near term) Isolate 12‐Hz and 14‐Hz lightly damped modes in SXM2, and suggest damping strategy.
4) (Immediate) Vibration characterization of SXM2 hexapod
5) (Short term) SPIE paper and talk on LBT vibration and mitigation
6) (On‐going) Data analysis backlog: Accelerometer dynamic test results
7) (On‐going) Data analysis backlog: PCB 9100C characterization test results
8) (On‐going) Data analysis backlog: Modal test results
9) (On‐going) OVMS accelerometer characterization

External inputs required to meet upcoming objectives

1) No external inputs required for quick‐look software testing
2) Modal tests on M2 “can” and hexapod require LBT at horizon, and possible swing‐out of SX M2 structure. Man‐lift required for access. On schedule for 3&4 April, 2010.
3) Same as 2.
4) Same as 2.
5) No external inputs for SPIE paper. But need data and “results.”
6) No external inputs required. Time constrained.
7) No external inputs required. Time constrained.
8) No external inputs required. Time constrained.
9) Contingent on LBTI purchase of additional accelerometers

Next major project milestone, critical path to meeting it, any concerns

1) Characterization and modeling of OVMS accelerometers prior to installation at LBT.
2) M2 structure characterization and modeling. Completion requires access to SXM2 and LBT elevation lock‐out for extended periods.
3) Characterization and strategy for 12‐Hz and 14‐Hz modes located at SX M2.

Percentage of the work now complete on this project. / If I (or the team) continue to work on this project at the rate realized for the last two months, it should be completed by MM/DD/YY.

A single representative number cannot be determined.
Estimates by task:

1) Vibration source identification: 15% complete.
2) Vibration mitigation: 0% complete. Estimated completion date TBD.
3) Vibration cataloging: Effort terminated. (80% before termination.)
4) OVMS accelerometer characterization (Tucson): 85% complete. Remaining dynamic testing pending LBTL acquisition of balance of accelerometers. Quiet tests terminated due to lack of appropriate test facilities.
5) OVMS cables tested for M2, M3 on both sides of LBT. Cables for M1 and rails have not been installed; M1 accelerometers also not installed. (60%)
6) LBT vibration specification generation: Complete, until revisions requested. (Specifications do not include methodology for verifying performance. Some specs cannot be measured for compliance.)
7) ARGOS vibration requirements for M2 (TBD)
8) SX M2
9) M2 swing-arm characterization 20% complete. Still need FEA analysis (5%), analysis (5%), modal testing (25%). Expected date of completion July 2010. 12-Hz and 14-Hz mitigation investigation can start in the near term, schedule permitting.
10) OVMS LabView quick-look software: 95% complete against original requirements. 90% complete against feature-creep and “user friendliness” requirements for third-party users. Quick-view software has been deployed and should be ready for general use in control room by 5 April, 2010.
11) Non-OVMS UEI vibration measurement system software development: 75%. Hardware configuration and packaging: 50%. This is not a software product; no completion date will be specified.
12) Modal analysis ANSYS FEA/Matlab baseline interface software: 0%. Completion hinges on time available to learn ANSYS: TBD. Schedule prohibits progress at this time.
13) Modal analysis system identification software: 0%. Schedule prohibits progress at this time.
14) OVMS accelerometer dynamic characterization data analysis and publication: 30%, progressing as time permits
15) SX M2 and chrome rod modal test data analysis and publication: 10%, progressing as time permits.

[For group manager if relevant:] This project is likely to extend for XX months beyond its originally projected completion date, with the impact.