The European E-ELT WHT LGS Test Facility Consortium

R.M.Myers[1], D. Bonaccini Calia[2], N. Devaney[3], S. Esposito[4], S. J. Goodsell[1], A. Goncharov[3], J. C. Guerra[5], H. Guillet de Chatellus[6], M. A. Harrison[1], R. Holzloehner[2], E. Marchetti[2], T. J. Morris[1], E. Pinna[4], J-P. Pique[6], S. Rabien[7], M. Reyes[8], E. Ribak[9], R. G. M. Rutten[5], H. Schnetler[10], M. Strachan[10], R. Stuik[11], R. G. Talbot[5]

1: CfAI, Department of Physics, Durham University, Science Laboratories, South Road, Durham DH1 3LE, UK
e-mail: r.m.myers@durham.ac.uk
2: ESO, Karl-Schwarzschild-Str. 2, D-85748 Garching b. Muenchen, Germany
3: NUI Galway, University Road, Galway, Ireland
4: Arcetri Astrophysical Observatory, Largo E. Fermi 5, 50125 Florence, Italy
5: Isaac Newton Group of Telescopes, Apartado de correos 321, E-38700 Santa Cruz de la Palma, Canary Islands, Spain
6: LSP-Grenoble, UMR5588, 140 Av. de la physique, BP 87 – 38402, Saint Martin d'Hères, France
7: MPIE Munich, Giessenbachstrasse, 85748 Garching, Germany
8: IAC, C/Via Lactea s/n, E-38200, La Laguna, Tenerife, Spain
9: Technion Haifa, Physics Department, Technion, Haifa 32000, Israel
10: UKATC, The Royal Observatory, Blackford Hill,Edinburgh, EH9 3HJ, UK
11: Leiden University, P.O. Box 9513, NL-2300 RA Leiden, The Netherlands

Abstract: A European collaboration has been formed to mitigate risks associated with LGS AO systems planned on the E-ELT. A Nasmyth platform on the 4.2m WHT will develop into a testbed. A seven year programme of work has been drafted to provide test infrastructure including the controlled environment GRAIL to support a set of risk mitigation developments and experiments.

1. Introduction

In preparation for the upcoming European Union Framework 7 (EU-FP7) call for proposals, a European consortium consisting of eleven institutes have formed to draft a seven year programme of work to address some of the risks associated with successfully creating Extremely Large Telescope (ELT) scale Laser Guide Star (LGS) Adaptive Optics (AO) systems.

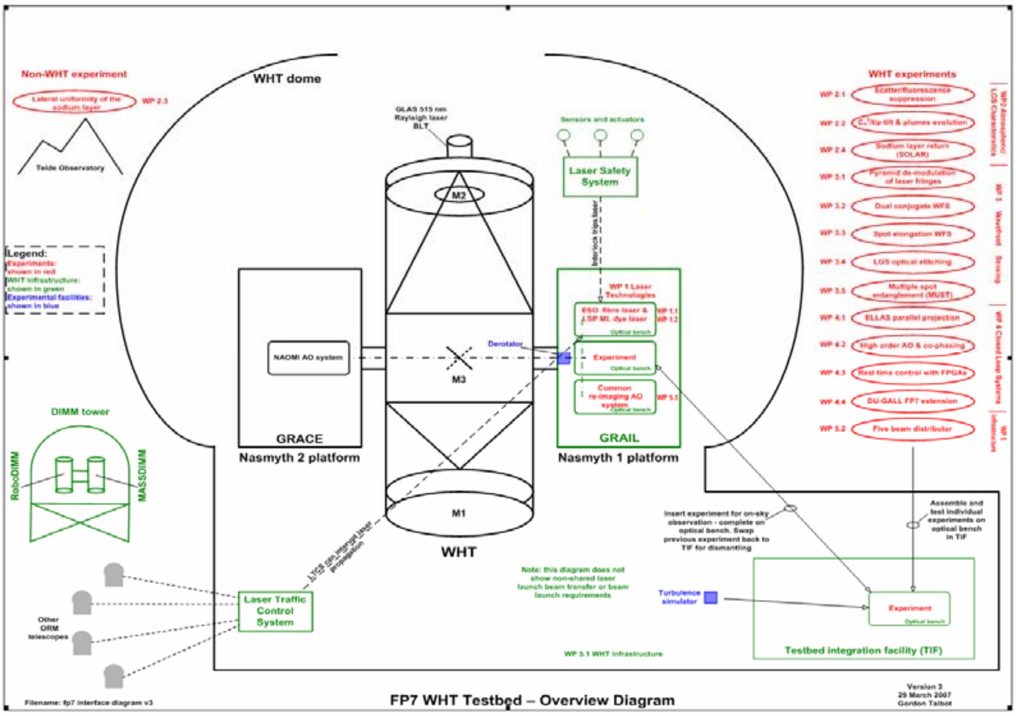

Figure 1 FP7 WHT Testbed – Overview Diagram

The target telescope for these ELT LGS risk mitigation experiments is the 4.2m William Herschel Telescope (WHT), which is operated by the Isaac Newton Group of Telescopes (ING), situated on the Roque de los Muchachos, La Palma. The telescope contains two Nasmyth platforms. Currently one hosts the 'Ground based Adaptive optics Controlled Environment' (GRACE), which is dedicated to the telescopes common-user AO facility, which consists of 'Nasmyth Adaptive Optics for Multi-purpose Instrumentation' (NAOMI), the 'Ground-layer Laser Adaptive optics System' (GLAS), the 'Optically Active System for Imaging Spectroscopy' (OASIS), the 'Isaac Newton Group Red Imaging Detector' (INGRID) and finally the 'Optimised Stellar Coronagraph for Adaptive Optics' (OSCA).

The other Nasmyth platform, currently contains a relatively simple enclosure with an undedicated optical bench available for guest instrumentation and experiments.

The EU-FP7 proposal is divided into two areas, the required experiment infrastructure development and the risk mitigating experiments themselves. Figure 1 contains an overview diagram.

2. Proposed Infrastructure: GRAIL

The main test-bed infrastructure will consist of the 'GRound-based Adaptive optics Innovative Laboratory' (GRAIL) which will be a dedicated structure at the Nasmyth focus of the WHT designed to facilitate visiting experiments by providing a controlled environment for the experiment systems.

GRAIL will be specifically designed to the overall requirements of the experiments – the requirements of which have been systematically captured from members of the collaboration. The major requirement is to provide space for the experiments and experimental facilities. Within the experimental room will be provision to mount up to three optical benches simultaneously, one dedicated for an experiment, one for the *Common Re-imaging AO System* and the third for the *Experimental Laser Facility*. It is anticipated that the *Common Re-imaging AO System* will remain in place while different experiments and experimental lasers will be interchanged as scheduled. Overall the GRAIL building will be pre-fabricated, with a planned overall dimensions of 8 m by 4 m by 3.5 m high. Internally it will be divided into an experimental room of ~ 26 m^2 and electronics room of ~ 6 m^2. This will provide space around the experiments for access while housing their electronics in a separate room minimising their environmental impact on the experiments. The proposed layout is shown in Figure 2.

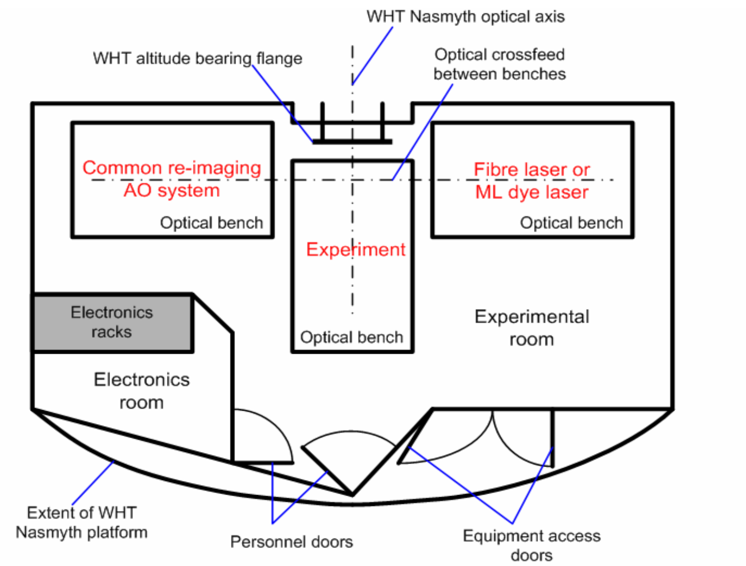

Figure 2 Proposed layout of GRAIL

The experimental space will have its cleanliness, humidity, temperature and light level stabilised. Laser light will be fed via the Nasmyth optical axis to and from the experiments or experimental facilities with the required wavelength range, field of view and throughput – including full aperture laser launch access through the WHT primary. All WHT services such as power, external liquid nitrogen filling of cryostats and dry instrument air will be provided.

3. Proposed Experiments

Currently ten European institutions have proposed 17 experiments that take advantage of the facilities provided by GRAIL, and the facilities that already exist at the WHT.

Pulsed sodium lasers are an important technology development for ELT based LGS AO that will allow some control over the effects of spot elongation and beam fratricide. ESO will undertake development of an 15W pulsed fibre-based laser. Fibre-based lasers hold several advantages over free-space lasers and have been identified as a potential system for the E-ELT. LSP will develop a 20W modeless sodium dye laser.

Novel LGS WFSing techniques have been proposed that attempt to counter the effect of focal anisoplanatism by launching the laser from the primary aperture of the telescope. Scatter and fluorescence of components that are common to both the launch and return paths of the laser can affect both LGS WFSing and scientific data. ING propose temporal and spectroscopic characterisation of the scatter and fluorescence in a real-telescope environment using both the 515nm GLAS Rayleigh LGS and the GRAIL sodium lasers.

The lateral uniformity of the sodium layer will be investigated via a collaboration between Technion and the IAC. This will not only provide important data for multiple-sodium LGS systems, but will also investigate the possibility of using non-uniformities within the sodium layer for performing MCAO-reconstruction

The LSP SOLAR (**So**dium **La**yer **R**eturn) experiment will examine the performance of the modeless sodium LGS both in 589nm operation and at the 330nm required for the generation of a polychromatic LGS. As well as photometry experiments at both wavelengths, a real-time LIDAR system will be installed to monitor the sodium layer profile and experiments undertaken that examine spot tracking of the pulsed sodium laser.

An investigation of the C_n^2 profile will be made through an evaluation of the GLAS Rayleigh LGS plume proposed by ING and Durham University using a Differential Image Motion Monitor (DIMM). The aim of this experiment is to provide real-time data of atmospheric data from the LGS plume itself that could be used to improve AO performance.

Several schemes for LGS WFSing will be trialed using the infrastructure provided by GRAIL. Two experiments are proposed from Technion. The first experiment examines tomographic WFSing using pyramid demodulation of fringes in the sodium layer. This approach means that the laser power required is reduced compared to previous proposals that analysed the sodium fringes using a Shack-Hartmann WFS.

ESO have proposed an investigation of sodium layer spot elongation on ELT scales. The experiment will perform Shack-Hartmann wavefront sensing on strongly elongated Sodium LGS to study in detail the problems related to the loss of sensitivity due to elongation and to test new centroid calculation algorithms which can improve the sensing process.

LGS perspective elongation correction and optical stitching will be investigated by the National University of Ireland in Galway. This experiment will stitch together the wavefronts from a 4 Rayleigh LGS asterism using a WFS that optically corrects for LGS perspective elongation.

The generation of an LGS using **Mu**ltiple **S**pot **T**angle (MUST) is a collaboration between Technion and the University of Durham that uses the overlap of several weak laser beams in the sky to create a single on-axis LGS. This approach reduces the effective vertical elongation of the LGS, thereby reducing spot elongation.

ELLAS (ESO Laser Layer Advanced Sensing Concept) uses a collimated beam projected from the full aperture of the WHT to provide a reference source. A 4-bucket shearing interferometer is then used to analyse the returning wavefront. This approach completely eliminates the problem of focal anisoplanatism.

The problem of co-phasing segmented mirrors is one that will affect all ELTs, but the interactions between AO and co-phasing correction loops have to be investigated. INAF Arcetri and Durham plan to test on sky the real interaction between a High Order AO loop and a Cophasing loop.

DU-GALL (Durham University Generalised Adaptive optics Laser guide star Laboratory) is supported by the UK Science and Technologies Facilities Council ELT technology development fund. It can support various on-sky and laboratory NGS and LGS AO configurations with up to 1k actuators.

Real-time control of ELT-scale AO systems requires very high data bandwidths. The IAC aims to demonstrate on-sky a real-time control system based upon FPGAs.

Finally, a re-imaging AO system (University of Leiden) will be developed for experiments that require an AO-corrected feed, and provide the a means of testing WFS concepts in a closed-loop system.