Status and plans for the LINC-NIRVANA Pathfinder

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Abstract. Layer-oriented Multi-conjugate Adaptive Optics systems apply two or more wavefront sensors (WFS), each with its own deformable mirror (DM) and each conjugate to a different turbulent layer in the atmosphere. Because these sensors apply correction in series, they are largely decoupled from one another, lending them to a phased commissioning approach. Commissioning instruments on large telescopes, while almost always successful in the end, can be, experience has shown, inefficient and difficult to schedule. For LINC-NIRVANA we plan to take advantage of the natural decoupling between the ground-layer subsystem (a 12-star pyramid WFS operating in conjunction with the LBT adaptive secondary) and the mid-high subsystem (an 8-star pyramid WFS working in conjunction with a Xynetics 349 actuator DM) to mitigate the difficulties that have been experienced commissioning complex instruments on large, over-subscribed, telescopes. Pathfinder is a test-bed, consisting of only those subsystems needed to operate, stand-alone, one of the two LINC-NIRVANA ground-layer subsystems. The Pathfinder effort will tease out top-level interface issues; while at the same time providing a valuable characterization of the Mount Graham ground-layer. To what extent will this ground-layer system provide a seeing-corrected image to the next WFS/DM pair in the LINC-NIRVANA system: the mid-high wavefront-sensor (MHWS)? We present status and plans for the LINC-NIRVANA Pathfinder effort, a novel approach for commissioning MCAO systems on large telescopes.

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1 Introduction

The LINC-NIRVANA (L-N) [1] instrument is shown in figure 1.

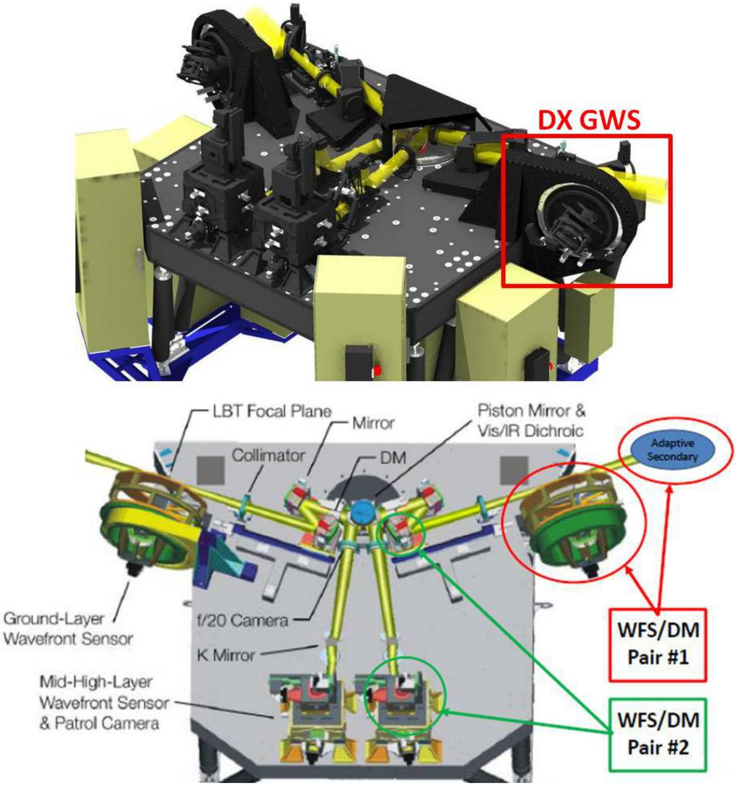

Fig. 1. Two views of the complete LINC-NIRVANA instrument. In the 3D CAD view shown on the top, the light path is indicated in yellow and can be seen passing through both arms of the complete AO system (the large yellow boxes depict the locations of the electronics cabinets). In the lower schematic, the light path appears, in yellow with green borders, and the two WFS/DM pairs of one arm are indicated. The GWS to be used for pathfinder is indicated by the red square in the top figure, and again within the large red circle in the lower figure. In the lower figure, the adaptive secondary to be controlled by the GWS is also indicated (within the red ellipse).

As seen in the lower panel, four individual wavefront-sensor / deformable-mirror (WFS/DM) pairs comprise the dual-arm, two-layer AO system.

One of these, indicated by the red outlines in figure 1, will commission early at the Large Binocular Telescope (LBT) as a stand-alone system. The configuration consists of 3 fundamental components (see figure 2): a ground-layer wavefront sensor (GWS), an infrared test camera (IRTC), and a support structure (commonly referred to as “the Foot”). These are discussed in sections 3, 4, and 5, respectively. In section 6 we cover software and in section 7, we provide our conclusions. We begin, in section 2 with a brief history of the project.

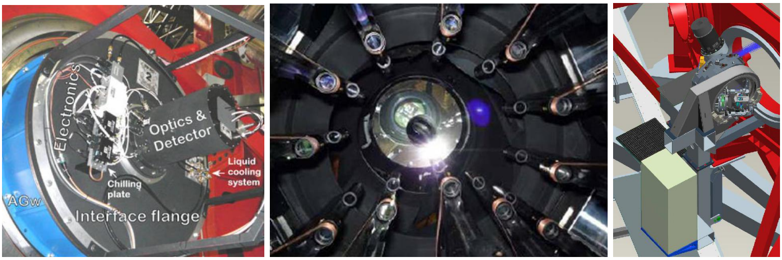

Fig. 2. The three components of Pathfinder. The three fundamental components of the Pathfinder are shown: the IRTC, scheduled to arrive at MPIA in early March, 2012 (left); the GWS, undergoing final pre-shipment tests at INAF-Padua (middle); and the support structure, in the final design stage with plans to initiate procurement during February, 2012 (right).

2 Brief History

The conceptual design for Pathfinder, a testbed for the LINC-NIRVANA ground layer wavefront sensor (GWS), was completed in March 2011 [2]. As described in that design, Pathfinder is not a new project, but rather a novel approach for building one of many testbeds required for testing individual components of the instrument. For example, a second testbed has been in place for several years at MPIA and is being used to test the high-layer wave front sensor and its DM (indicated by the green outlines in the figure 1 lower panel) in a closed loop experiment [3].

The decision to build the GWS testbed as one that would reside at the telescope, instead of in a lab at MPIA, arose from the need to control the adaptive secondary and, in general, as a method for retiring some of the risk associated with developing and testing instrument-to-telescope interfaces.

As of this writing, the GWS is undergoing final unit tests at INAF-Padua, the IRTC is scheduled to arrive at MPIA in early March, and the support structure detailed design is in progress with plans to initiate procurement in early 2012.

3 Ground-layer wavefront sensor

The L-N ground-layer wavefront sensor (GWS) picks off the outer annulus of the F15 beam as it enters the L-N system (approximately six arcminute outer diameter and two arcminute inner diameter[1]) [4]. Up to 12 AO guide stars in that field are then sensed by individual pyramids and are then optically combined.

For a given asterism, positioning each pyramid, in concert with the pointing of the LBT, will require only traditional methods, but at a new level of complexity. Gaining experience with this acquisition procedure, and the instrument-to-telescope software interface it requires (before full L-N instrument commissioning) is seen as one of several key advantages to the Pathfinder project.

4 IRTC

The LBT Infrared Test Camera (IRTC) has been used with great success on previous commissioning campaigns at LBT to record AO corrected images as delivered by the adaptive secondary [7] [8]. For Pathfinder, the camera will be used ”as is” with no planned changes or extensions. The electronics and liquid cooling system external components (see figure 2) will be mounted near the camera on the foot (see section 5). In addition to serving as a science camera, the IRTC will be used as an acquisition camera, and thereby serve to commission and debug a modified version of the patrol camera software planned for the full instrument (see section 6).

5 Foot

A preliminary design for the Pathfinder support structure (dubbed ”the Foot”) appears in the right panel of figure 2. This structure accommodates those portions of the full instrument required for Pathfinder (see red outline of figure 1 top panel), and therefore, in broad terms, simply provides

[1] Due to vignetting the effective inner radius is 2.88 arcminutes.

a platform with the height and dimensions of that small portion of the full L-N bench. To ease use in the assembly hall and lab environments, the lower half (approximately one meter) will be detachable which will bring the working surface to a more comfortable one meter height.

6 Software

Functionality	Percentage testable with Pathfinder	Testable Interfaces
Wavefront Control Loop (including calibration)	**60%** – The 40% not testable with Pathfinder consists primarily of the mid-high WFS and DM (see figure 1 right-hand panel, green outline) which will employ a pure software-on-Linux solution [9]. All L-N modes that control the adaptive secondary (Pathfinder and a pre-MCAO L-N mode called LINC to follow Pathfinder) employ the same Microgate FPGA units that were used for FLAO [8].	LBT adaptive secondary (transmitting slopes at the frame rate, uploading reconstructors, receiving diagnostics)
Field Acquisition	**30%** – Field acquisition with the final L-N instrument will be carried out using a patrol camera dedicated to this purpose. Whereas, for Pathfinder, the IRTC will fill this role. Although there are many differences (FoV, software packaging, detector format, blind-versus-visible guide stars, etc), the fundamental algorithms intended for the final system will be tested.	LBT presets, offsets, and collimation adjustments via the ICE [10] instrument interface (IIF) [11].
Field Rotation	**60%** – The rotator control for the mid-hight WFS (a K-mirror) will not be tested, however, much of the GWS rotator software (e.g., receiving trajectories from the LBT TCS) is common.	Receive trajectories via the ICE [10] instrument interface (IIF) [11].

Table 1 - L-N software to be tested with Pathfinder. For the three fundamental areas of L-N AO software functionality, we give, in the middle column, the percentage testable with Pathfinder (along with a brief description of how that percentage was estimated) and, in the right-hand column, which software interfaces at LBT will be testable. Testing LBT interfaces stands as one of the primary goals of the Pathfinder project.

The three fundamental areas of the AO software for L-N, together with specifics of what portions will be tested and against what interfaces, are shown in table 1. The other fundamental areas of L-N software, in particular, instrument control, detector read-out, beam control, and fringe tracking, are not listed in this table. These areas will be thoroughly tested, but in test beds separate from Pathfinder. They either do not have extensive telescope interfaces to be checked (e.g., instrument control and detector read-out) or will be tested by a simplified mode of L-N (”LINC” mode) that follows Pathfinder at the telescope but goes on to combine the two telescope beams interferometrically, but with only single-star AO. LINC mode will preceed the full L-N instrument and be used to test beam control and fringe tracking ahead of the full-up, MCAO-based, system.

7 Conclusion

We will commission a single wave front sensor at LBT ahead of the full instrument. By conducting this test experiment at the telescope (as opposed to the traditional approach of using a laboratory at the home institution), we will retire risk and identify critical interface problems early; and thereby keep the task of solving those interface problems off of the critical path.

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