CANARY: An on-sky instrument development test bench open to the community

[a*]T. Morris, [b]E. Gendron, [b]G. Rousset, [c]D. Bonaccini Calia, [a]L. Bardou, [d]M. Centrone, [a]J. Osborn, [e]F. Chemla, [d]T. Buey, [a]L. Staykov, [a]N. Bharmal, [a]M. Townson, [e]M. Cohen

[a]Centre for Advanced Instrumentation, Department of Physics, Durham University, Durham, DH1 3LE, UK; [b]LESIA, Observatoire de Paris, 5 place Jules Janssen, 92195 Meudon Cedex, France; [c]European Southern Observatory, Karl-Schwarzschild-Straße 2, 85748 Garching bei München, Germany; [d]INAF – Osservatorio Astronomico di Roma, Via di Frascati 33, 00040 Monte Porzio Catone, Italy; [e]GEPI, Observatoire de Paris, 5 place Jules Janssen, 92195 Meudon Cedex, France

ABSTRACT

The CANARY AO system was developed to provide on-sky demonstration of multiple NGS/LGS tomographic AO and later to assess the impact of ELT-scale LGS perspective elongation on Shack-Hartmann wavefront sensor performance. CANARY completed these initial research goals in 2016, and the database of archived on-sky open- and pseudo-open loop AO telemetry data was made available to the community in 2018. Through the H2020 OPTICON program, and with support from ESO and the Isaac Newton Group of Telescopes, access to CANARY has now been opened to the instrumentation community through a competitive call for proposals. CANARY is now available to use as a test bench for the on-sky development of new instrumentation concepts or validate AO performance models at the 4.2m William Herschel Telescope. The first on-sky runs in 2019 have now been completed and an additional call is planned to allocate a total of 5-10 nights of on-sky time in 2020/2021. In this poster we describe the potential CANARY configurations offered to the community (including SCAO, NGS-only tomographic AO and sodium LGS AO), how to apply for time and gain access to the existing archive of on-sky CANARY data.

Keywords: Instrumentation, Adaptive Optics

1. INTRODUCTION

CANARY is an on-sky tomographic adaptive optics demonstrator installed at the 4.2m William Herschel Telescope (WHT) in the Canary Islands. Since initial commissioning in 2010, it has since provided the first on-sky demonstrations of NGS[1] and LGS MOAO[2], LTAO[3][4] and tomographic LQG control[5] as well as hosting several visitor experiments. CANARY was developed by an EU-wide consortium, led by Durham University and Observatoire de Paris, LESIA. The WHT is operated by the Isaac Newton Group of Telescopes (ING).

Through the H2020 OPTICON program funds have been made available that allow members of the worldwide (*not just EU*) instrumentation community to apply for time using CANARY to test novel instrumentation concepts that are at a stage of development where they require on-sky demonstration before being adopted as a core component of a facility-class instrument. This is typically taking a concept from technology readiness level 3-4 to 5-7, dependent on experiment. This can include, but is not limited to, tests of new wavefront sensors, instrumentation that requires an AO corrected focus to operate, or new calibration and control techniques that can be tested within the real-time control system. Up to 20 nights of observing time are available to be shared between several projects that will be allocated before the end of 2020. Observations will be supported by members of the CANARY team who will be able to assist with the design, installation and operation of selected experiments with CANARY.

* t.j.morris@durham.ac.uk

In this paper we first provide details of the experimental setup offered and describe the AO performance that is typically achieved with CANARY. We then describe the application procedure and detail how experiments are selected. Finally we provide brief descriptions of the experiments/visitor instruments that were selected for on-sky operations in 2019 and some information of the future of this program.

2. FACILITIES OFFERED

The CANARY experiment has been in operation since 2010 and is installed on a large, gravity stable bench in a temperature-controlled environment at the Nasmyth port of the WHT. The current CANARY setup offered for OPTICON-funded observations comprises the following:

- Closed-loop tomographic NGS mode, with 3 off-axis NGS SH-WFS that can be positioned within a 2 arcminute derotated field
- An on-axis NGS SH-WFS for calibration and SCAO operation
- An on-axis LGS SH-WFS on a removable kinematic bench
- A low-order 52-actuator closed-loop DM, tip/tilt mirror and/or a higher order 241-actuator closed/open-loop DM (depending on control configuration)
- A reconfigurable real-time control system running on standard CPU machines, written in C/Python.[6]
- A comprehensive telescope simulator containing NGS and LGS sources, as well as 2 turbulent phase screens and a range of pupil alignment and calibration masks
- A K-mirror image derotator for sky tracking
- A 3’ diameter FOV acquisition camera

A schematic of the CANARY bench layout and an image of the bench (with the optional blue NIR test camera installed in the region made available for visitor instruments) is shown in Figure 1.

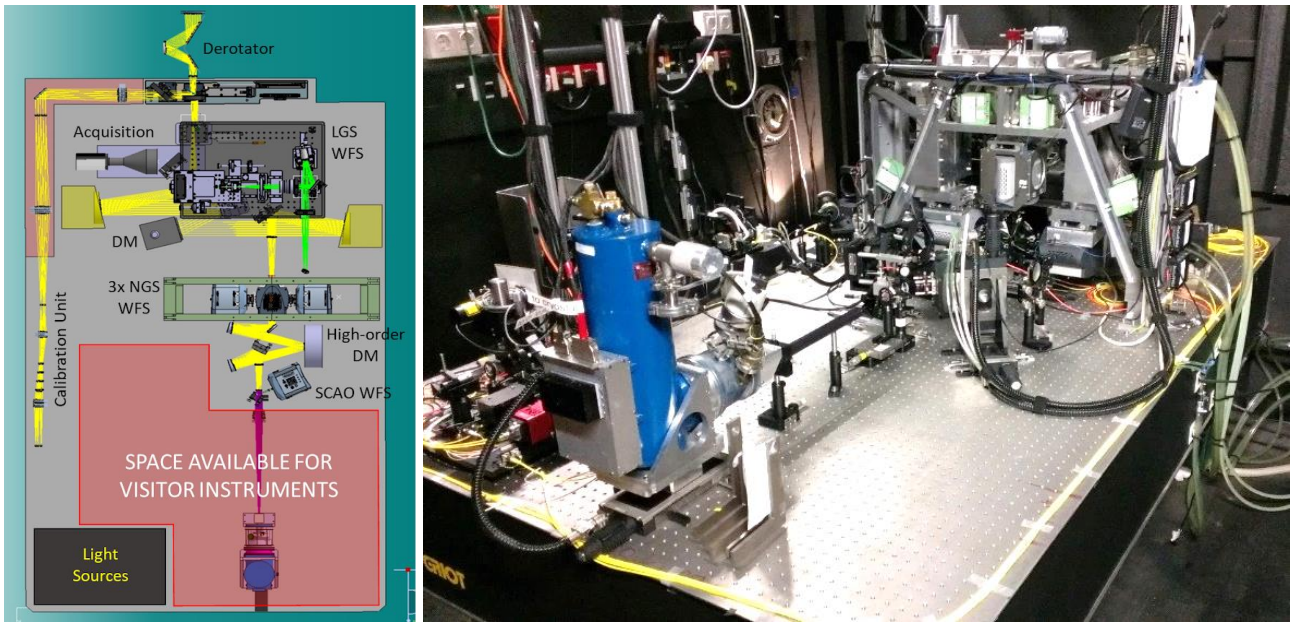

Figure 1 The CANARY system installed at the WHT Nasmyth port. Left: A schematic layout showing the optical path and principal components, as well as the space envelope that can be made available for visitor instrumentation (approximately 1 x 1.2 m in size).

CANARY is not a facility AO system, therefore requires significant levels of support from the CANARY team to assist with installation and operation of the system. This also provides a benefit in that we can modify the system as required to support a wide range of back-end instrumentation and experiments. There are however some caveats when considering the types of experiments that CANARY can support:

- CANARY is a low order 7x7 WFS subaperture AO system designed to test tomographic control, not provide a high Strehl ratios. We typically achieve a 20-30% H-band Strehl ratio when operating in tomographic mode. SCAO can be offered with 14x14 subapertures that will undergo on-sky performance testing in July 2019.
- CANARY is limited to guide stars brighter than R=11. When operating in multi-NGS mode, there are ~50 targets that can be observed with CANARY, so do not propose experiments that require a high-sky coverage.
- CANARY is not typically able to support astronomical science observations partially due to low throughput, however demonstration astronomical science observations on bright targets using new instrumentation is welcomed.

Whilst the CANARY AO system at the WHT provides the primary facility offered for testing, we also operate other facilities at the observatory upon which time can also be applied for:

- A sodium profiling (6' field 589nm imager) instrument that can be installed at the 2.5m Isaac Newton Telescope (INT)
- A high-vertical resolution Stereo-SCIDAR system, that can also be installed at the 2.5m INT[7]
- A 20W sodium LGS and launch system launched from an auxiliary telescope positioned approximately 40m from the WHT optical axis.

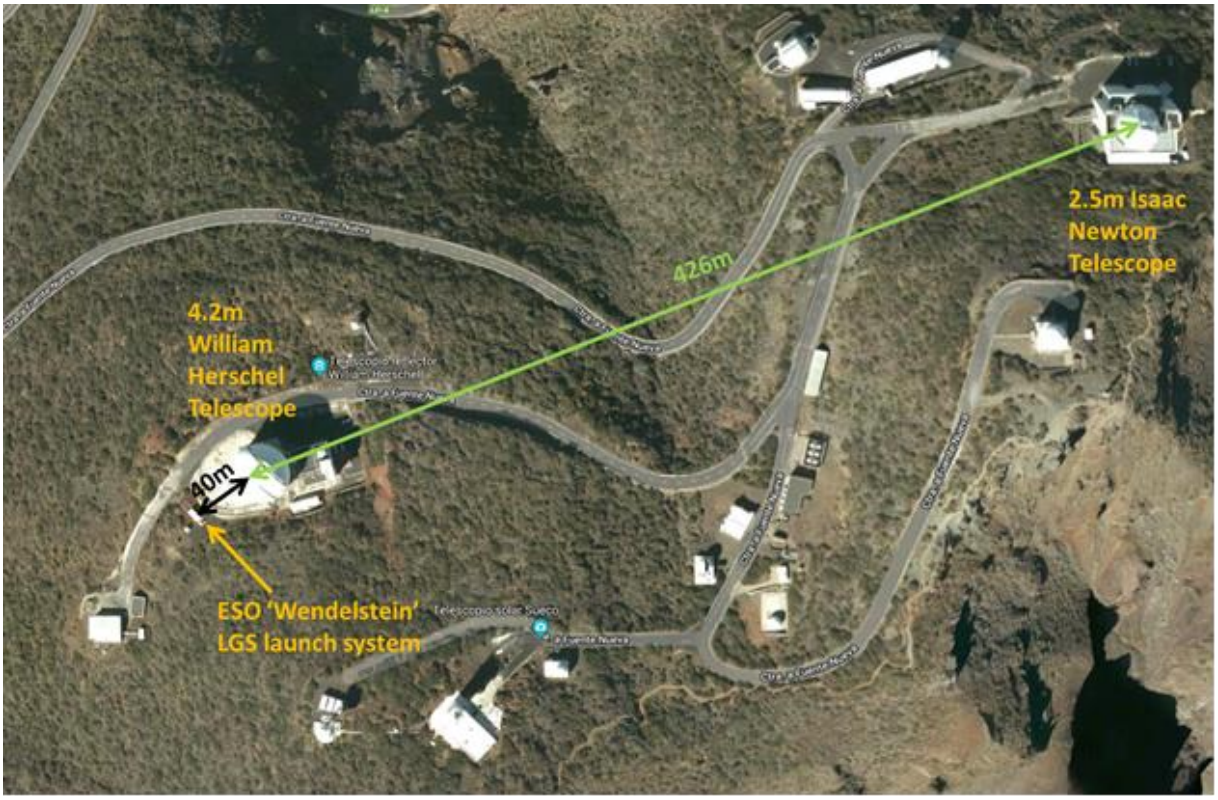

Figure 2 Distance between facilities offered as part of the OPTICON-funded setup.

The ESO "Wendelstein" Laser Guide Star Unit (WLGSU), developed and operated by ESO/INAF-Roma, provides the ability to recreate ELT-scale elongation when observed with CANARY. The two instruments on the INT cannot be installed at the same time, and offer the ability to either provide high-resolution turbulence profiles (measurements every 100-200m in altitude up to a maximum altitude of ~20km dependent on observed asterism, or the ability to monitor the sodium density profile. The WHT, INT and the WLGSU are all linked via a software 'geometry server' that ensures that the three telescopes remain aligned during operation. The ING operate a laser traffic control system to avoid collisions with other telescopes at the observatory.

3. APPLYING FOR TIME

To access these facilities, researchers must prepare a detailed experimental proposal that is submitted in response to a call (of which there has only been one to date). Time on any of the facilities offered by OPTICON is then awarded by an independent time allocation panel comprising members of the astronomical instrumentation development community. The panel assesses and ranks proposals based on the following criteria:

- Technical feasibility. In addition to the assessment of the panel, members of the CANARY team will provide details on if the proposed experiment is supportable within the effort available to the project.
- Scientific merit. This is assessed both in terms of the current scientific merit of the technology/technique being tested and the scientific performance that would be enabled by an eventual instrument that which used the technology/technique.
- Alignment with the research goals of the OPTICON program
- Available time at the telescope. Typical run durations are 3-5 nights per semester and we would expect to be able to support one, maybe two experiments (depending on complexity) during a single run.

During the run up to the proposal submission, researchers developing proposals can expect that Durham, LESIA and ESO will provide access to all CANARY and WLGSU documentation and design files, and will be available to answer questions on the best way to integrate and operate their experiment with the CANARY systems. We note that if researchers wish to apply for time that doesn't use CANARY, and just require access to the Nasmyth focus with an empty optical bench, this is also possible.

Proposals may be submitted by any institute/user group within the rules for Trans-National Access[*] provision under H2020. To comply with the Grant Agreement between the OPTICON community and the EC at least 50% of the partners involved in a proposal must work in an institution in the EU or "H2020 associated country". As there is no alternative access program for CANARY, instrument and installation location restrictions for applicants do not apply. Please contact the authors if you're unsure as to your eligibility status after reading information in the link below.

The CANARY team expect to put out the next call for proposals early in 2020, for experiments in November/December 2020. Both the WHT and INT telescopes are currently undergoing major programmes to prepare for the arrival of the WEAVE spectrograph at the WHT and HARPS3 spectrograph at the INT. This may have an impact on telescope availability:

- WHT access for 20A is unlikely as WEAVE will be being installed.
- WHT access for 20B is under negotiation, but we would expect to be on-sky before the end of 2020.
- We do not expect access to the INT to be impacted on the timescale of H2020 funding.

In late 2018 the first call for proposals was issued and five experiments were awarded on-sky time on CANARY or at the INT:

1. High-performance control scheme based on wind and turbulence profiles (FR)
2. Diffraction-limited IFU with astrophotonic-fed high resolution spectrograph (NL/DE/IT)
3. Two new high-sensitivity post-focal AO WFSs (FR/UK)
4. Astrophotonic pupil interferometer (DE)
5. High-resolution spectroscopy using adiabatic tapered fibres (UK)

A total of two runs with CANARY, and one run with the wide-field imager on the INT were arranged. The first CANARY run combined experiments 1-3 over a 5-night period in July 2019, with the second run in August 2019 for experiment 4. Experiment 5 was allocated time on the INT, where only seeing limited observations are possible, with a 3-night run in September 2019.

3.1 Future program

The H2020 OPTICON program finishes at the end of 2020, and there is currently no additional funding to continue this program beyond this date. However, we will be applying to the EU for continued funding to support on-sky CANARY

[*] https://www.astro-opticon.org/h2020/tna/index.htm

observations into the future. In addition to CANARY we hope to gain access to additional on-sky AO test facilities in France, Italy and Spain. This will provide the instrumentation community with access to a much wider range of facilities and increase the number of tests that can be supported. Setting these on-sky testbenches up as EU-wide facilities also allows us to fund additional effort from the AO instrument developers to support visitor instrumentation during development and operation. We also are proposing that the time allocation panel will be able to award time at any point between 2021-2024 up to 2 years in advance so that instrument developers can be confident that they will have the time to develop (and in some cases secure funding) for their on-sky experiment.

4. CONCLUSION

The CANARY on-sky AO testbench, and associated sodium laser guide star system are being offered to the instrumentation development community for rapid prototyping and testing of new instrumentation concepts. The CANARY testbench and sodium laser guide star system have now had their first on-sky runs funded by the H2020 OPTICON program. The facilities offered through this program allow instrument developers to test new concepts in a real observatory environment, whilst supported by experienced AO teams. This greatly reduces the time and cost taken to develop new instrumentation concepts, hopefully decreasing the time taken for advanced technologies to be deployed in future facility-class instrumentation.

Further details of the OPTICON-funded CANARY access program, including details of the CANARY system and upcoming calls can be found on the CANARY OPTICON webpages[*]. We hope to continue and expand this program to other telescopes in the future and look forward to the new technologies that will be developed under the current and future programs.

ACKNOWLEDGEMENTS

Horizon 2020: This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement number 730890. CANARY was funded in the UK through STFC via grants PP/E007651/1, ST/M007669/1, ST/L003457/1 and Durham University. In France it has been funded via ANR Mauii, INSU and the Observatoire de Paris. The development of the WLGSU was supported by ESO. The William Herschel and Isaac Netwon Telescopes is operated on the island of La Palma by the Isaac Newton Group of Telescopes in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias. The authors would especially like to thank the staff at the Isaac Newton Group of Telescopes for their continued support.

REFERENCES

[1] Gendron et al., "MOAO first on-sky demonstration with CANARY", A&A 529, L2 (2011)
[2] Gendron, E., *et al*, "Detailed analysis of on-sky tomography with Laser Guide Stars by the MOAO demonstrator Canary", Proc SPIE 9148 (2014)
[3] Morris *et al.*, "CANARY Phase B: On-sky open-loop tomographic LGS AO results", Proc. SPIE 9148, 9148-1L (2014)
[4] Morris, T., *et al*, "Multiple Object Adaptive Optics: Mixed NGS/LGS tomography", Proc. of the Third AO4ELT Conference 1, 114 (2013)
[5] Sivo, G., *et al*, "First on-sky validation of full LQG control with vibration mitigation on the CANARY MOAO pathfinder", Proc. of the Third AO4ELT Conference 1, 127 (2013)
[6] Basden, A.G., Geng, D., Myers, R. and Younger, E., "Durham adaptive optics real-time controller", Applied Optics 49(32), 6354-6363 (2010)

[*] https://sites.google.com/view/opticon-ao/canary

[7] Shepherd, H., Osborn, J., Wilson, R.W., Butterley, T., Avila, R., Dhillon, V.S., and Morris, T.J., “Stereo–SCIDAR: Optical turbulence profiling with high sensitivity using a modified SCIDAR instrument”, MNRAS, 437, 3568-3577 (2013)