SMARTSAT
COOPERATIVE RESEARCH CENTRE

THE UNIVERSITY OF WESTERN AUSTRALIA | University of South Australia | Australian Government Department of Defence Science and Technology | THALES AUSTRALIA | ThalesAlenia Space | GOONHILLY EARTH STATION

P1-01/18: Coherent Free-Space Optical Communications

Organisation Lead Participants: S. Schediwy[1], G. Lechner[2], B. Clare[3], M. Clark[4], C. Laborde[5], B. Gough[6].

Introduction

This project is led by the University of Western Australia with partners University of South Australia, Defence Science and Technology Group, Thales Australia, Thales Alenia Space, and Goonhilly Earth Station. The project was initially funded for one year (P1-01), and it has since been extended for a further three years and two months (P1-18).

Aims

The project aims to demonstrate optical fibre-like data transfer rates over atmospheric free-space communications links. Theses links include:

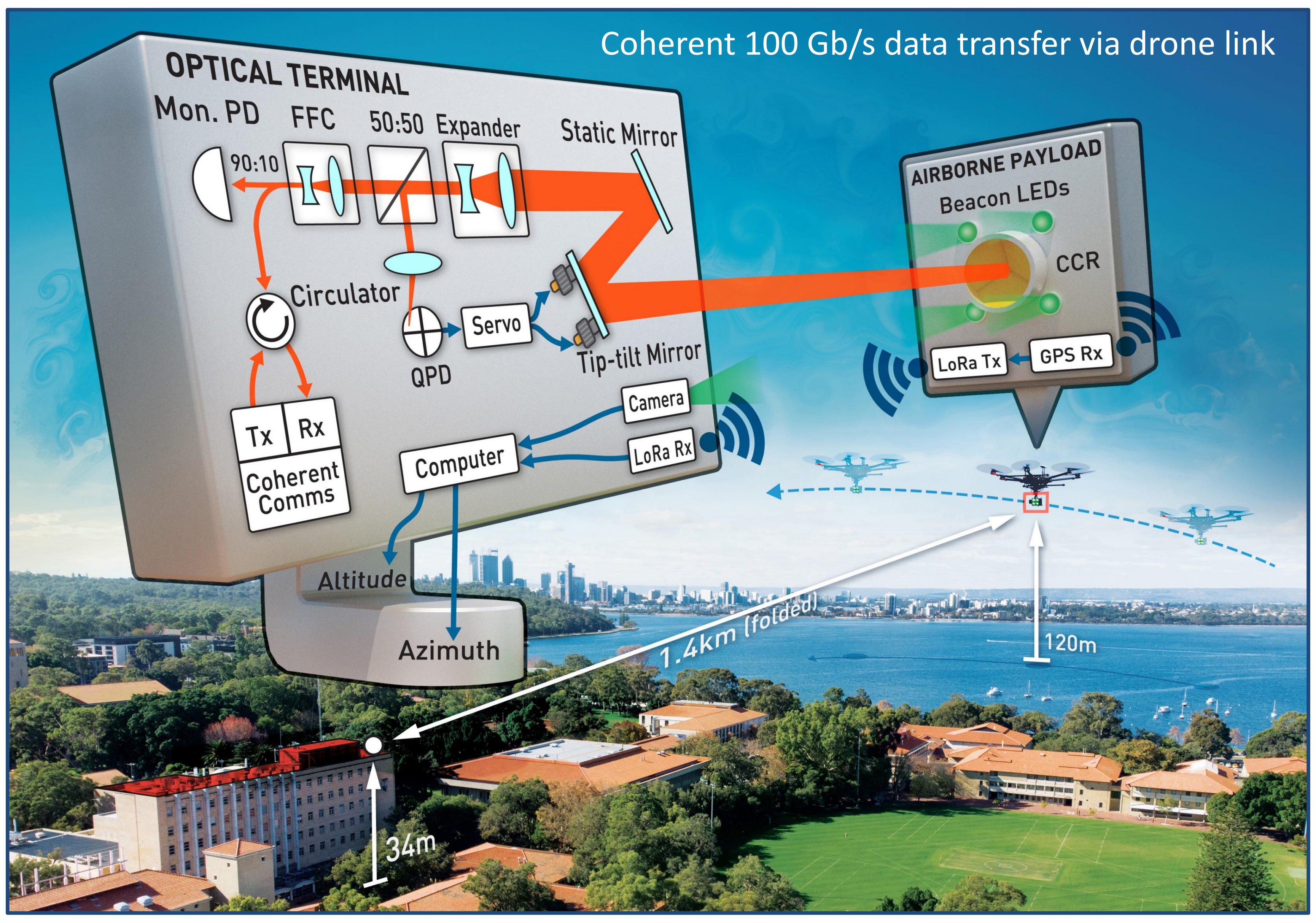
- a horizontal link with equivalent turbulence as a link between ground-LEO,
- a 10 km horizontal link over water and that exhibits extreme turbulence,
- a slant-path link to a drone flying at LEO angular rates, and
- a 10 km slant-path link via a light aircraft.

Methods

To demonstrate the aims of the project, our team has transferred the following optical signals over the aforementioned free-space links

- a 100 Gb/s coherent DP-QPSK communications signal,
- a proxy-NASA high-photon efficiency lunar communications scheme,
- an ultra-precise optical positioning and velocimetry signal, and
- an ultra-stable optical timescale transfer signal.

To enable these capabilities, we use a novel combination of adaptive optics technology employed on large-scale astronomical telescopes, and where required, phase-noise suppression technology developed for the SKA radio telescope. One experimental implementation is shown in the figure below.



Student Training

(* current)

PhD: S. Karpathakis*, A. Frost*, A. McCann*, S. McSorley*, B. Dix-Matthews
Masters: A. McCann, J. Collier, M. Heber, J. Bonavita, E. Zandi, C. Winter
Honours: J. Wallis*, A. Frost, T. Digney, and S. McSorley

Results

Ten of the eleven project Activities have been successfully completed. To date, the project has delivered eight technical reports; one PhD, six Masters, and three Honours theses; ten journal papers (nine published, one under review), and numerous conference outputs. Highlights of recent work is shown in the figures below.

Drone and optical payload | Demonstration at Exercise Talisman Sabre | Gen3 optical terminal | Optical terminal GUI | Aircraft used in 10 km slant-path | 10 km slant-path demonstration

SmartSat Journal Publications

B. Dix-Matthews, et al. *Atmospheric turbulence characterization with simultaneous measurement of phase, angle-of-arrival, and intensity in a retroreflected optical link*. Submitted Optics Letters (2023).

S. Karpathakis, et al. *High-bandwidth coherent optical communication over 10.3 km of turbulent air*. Applied Optics **62** (2023) G85.

B. Dix-Matthews, et al. *Experimental demonstration of velocimetry by actively stabilised coherent optical transfer*. Phys. Rev. Appl. **19** (2023) 054018.

B. Dix-Matthews, et al. *Optical Frequency Transfer for Geopotential Difference Measurements via a Flying Drone.* Opt. Express **31** (2023) 15075.

S. Karpathakis, et al. *Ground-to-Drone Optical Pulse Position Modulation Demonstration as a Testbed for Lunar Communications*. Drones **7** (2023) 99.

S. Walsh et al. *Adaptive optics LEO uplink pre-compensation with finite spatial modes*. Optics Letters **48** (2023) 880.

S. Walsh et al. *Demonstration of 100 Gbps Coherent Free-Space Optical Communications at LEO Tracking Rates*. Sci. Rep. **12** (2022) 18345.

S. Walsh, et al. *Angle-of-arrival variability of retroreflected lasers despite atmospheric reciprocity.* Optics Letters **47** (2022) 1920.

D. Gozzard, et al. *Ultra-stable Free-Space Laser Links for a Global Network of Optical Atomic Clocks*. Physical Review Letters **128** (2022) 020801.

B. Dix-Matthews, et al. *Ultra-wideband free-space optical phase stabilisation*. IEEE Communications Letters **25** (2021) 1610.

1. University of Western Australia, 2. University of South Australia, 3. Defence Science and Technology Group, 4. Thales Australia, 5. Thales Alenia Space, 6. Goonhilly Earth Station

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