RadComms 2022

New Frontiers for Optical Communications

15th November 2022

Mr Peter Kerr
Coordinator, Defence & National Security
SmartSat CRC

SMARTSAT COOPERATIVE RESEARCH CENTRE

Australian Government
Department of Industry, Science, Energy and Resources

AusIndustry
Cooperative Research Centres Program

With contributions from Dr Gerald Bolding (DSTG) and A/Prof Sascha Schediwy (University of WA)

Significant Space R&D coalition of researchers & industry…

SmartSat Services
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cygence
office of planetary observations
LEO LABS
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NEUMANN SPACE
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MELBOURNE SPACE PROGRAM
THALES
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EM SOLUTIONS Radio waves at work
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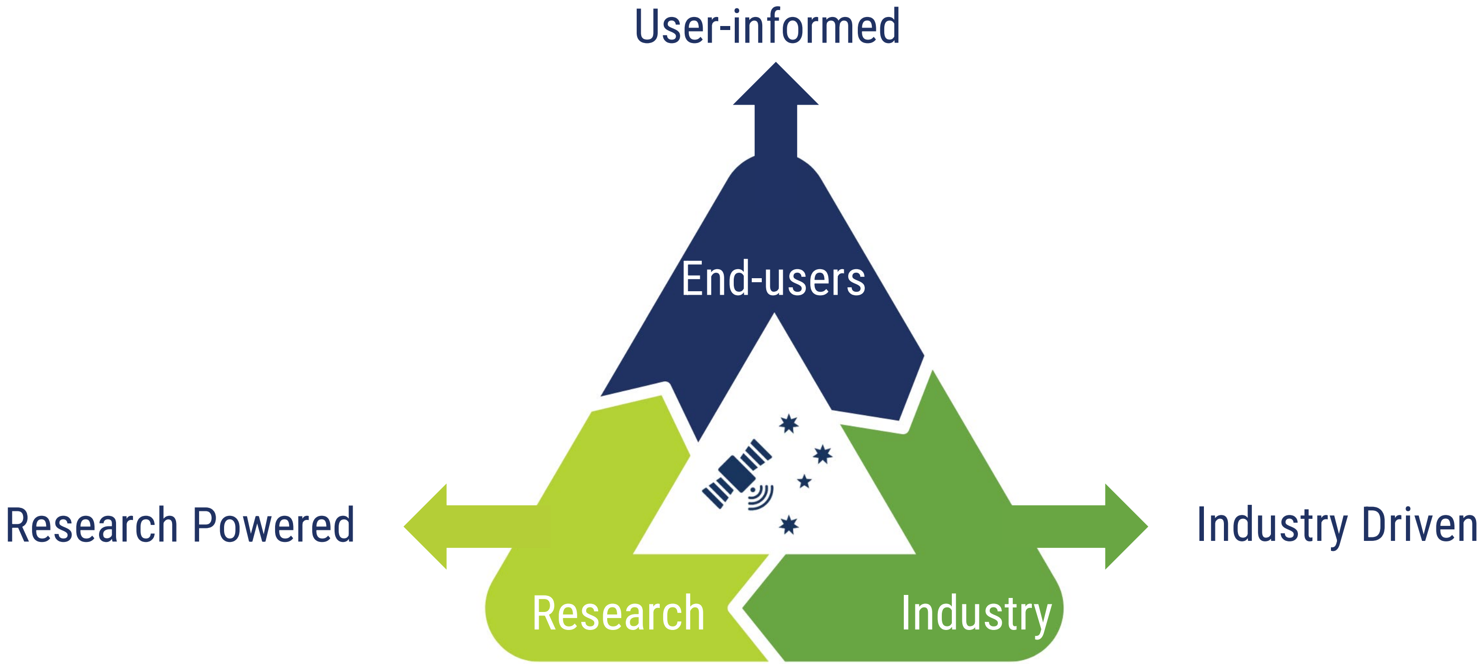
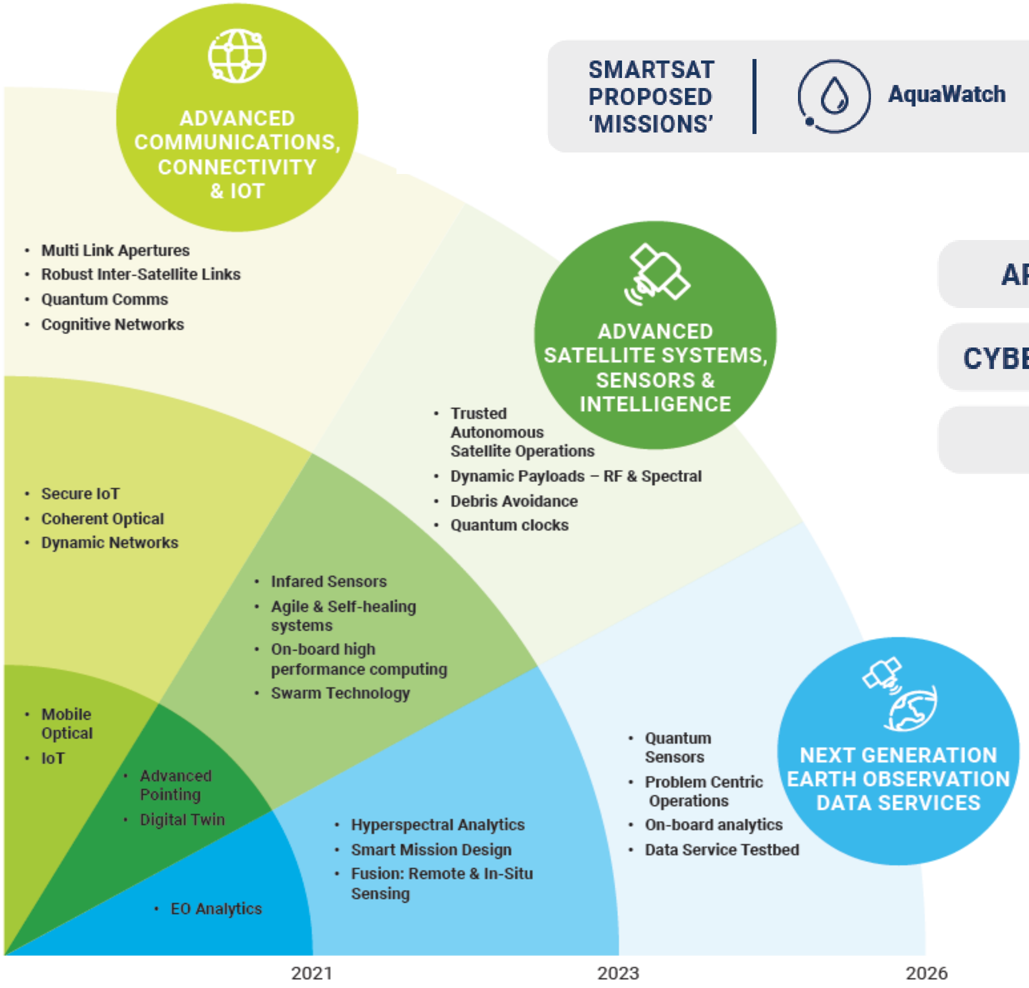
Innovation through collaboration

The SmartSat CRC Model…



SmartSat Technology Roadmap



SMARTSAT PROPOSED 'MISSIONS'

- AquaWatch
- Disaster Resilience
- Indo-Pacific Inter-Connector

Cross-cutting Themes

- ARTIFICIAL INTELLIGENCE
- CYBER-SECURITY & RESILIENCE
- SPACE GOVERNANCE

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Why Fund Optical Communications Research?

SmartSat Priority from Technology Roadmap

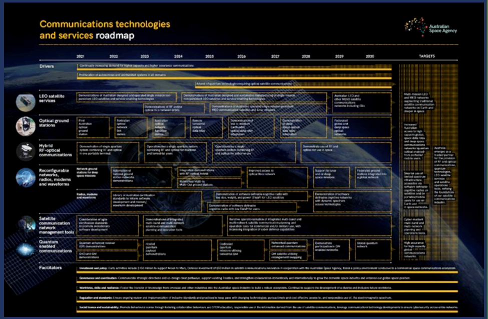
- Mobile Optical
- Coherent Optical
- Quantum Communications

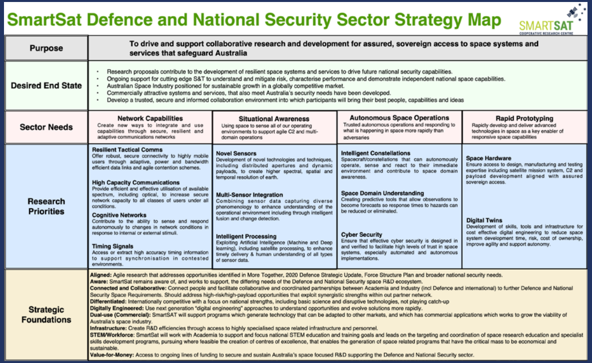
Australian Space Agency Priority

- Optical Ground Stations
- Hybrid RF-Optical communications
- Quantum enabled communications

Defence Interest

- High-capacity Communications
- Resilient Tactical Communications





SmartSat Defence and National Security Sector Strategy Map

Purpose	**To drive and support collaborative research and development for assured, sovereign access to space systems and services that safeguard Australia**			
Desired End State	• Research proposals contribute to the development of resilient space systems and services to drive future national security capabilities. • Ongoing support for cutting edge S&T to understand and mitigate risk, characterise performance and demonstrate independent national space capabilities. • Australian Space Industry positioned for sustainable growth in a globally competitive market. • Commercially attractive systems and services, that also meet Australia's security needs have been developed. • Develop a trusted, secure and informed collaboration environment into which participants will bring their best people, capabilities and ideas			
Sector Needs	**Network Capabilities** Create new ways to integrate and use capabilities through secure, resilient and adaptive communications networks	**Situational Awareness** Using space to sense all of our operating environments to support agile C2 and multi-domain operations	**Autonomous Space Operations** Trusted autonomous operations and responding to what is happening in space more rapidly than adversaries	**Rapid Prototyping** Rapidly develop and deliver advanced technologies in space as a key enabler of responsive space capabilities
Research Priorities	**Resilient Tactical Comms** Offer robust, secure connectivity to highly mobile users through adaptive, power and bandwidth efficient data links and agile contention schemes. **High Capacity Communications** Provide efficient and effective utilisation of available spectrum, including optical, to increase secure network capacity to all classes of users under all conditions. **Cognitive Networks** Contribute to the ability to sense and respond autonomously to changes in network conditions in response to internal or external stimuli. **Timing Signals** Access or extract high accuracy timing information to support synchronisation in contested environments.	**Novel Sensors** Development of novel technologies and techniques, including distributed apertures and dynamic payloads, to create higher spectral, spatial and temporal resolution of earth. **Multi-Sensor Integration** Combining sensor data capturing diverse phenomenology to enhance understanding of the operational environment including through intelligent fusion and change detection. **Intelligent Processing** Exploiting Artificial Intelligence (Machine and Deep learning), including satellite processing, to enhance timely delivery & human understanding of all types of sensor data.	**Intelligent Constellations** Spacecraft/constellations that can autonomously operate, sense and react to their immediate environment and contribute to space domain awareness. **Space Domain Understanding** Creating predictive tools that allow observations to become forecasts so response times to hazards can be reduced or eliminated. **Cyber Security** Ensure that effective cyber security is designed in and verified to facilitate high levels of trust in space systems, especially automated and autonomous implementations.	**Space Hardware** Ensure access to design, manufacturing and testing expertise including satellite mission system, C2 and payload development aligned with assured sovereign access. **Digital Twins** Development of skills, tools and infrastructure for cost effective digital engineering to reduce space system development time, risk, cost of ownership, improve agility and support autonomy.
Strategic Foundations	**Aligned:** Agile research that addresses opportunities identified in More Together, 2020 Defence Strategic Update, Force Structure Plan and broader national security needs. **Aware:** SmartSat remains aware of, and works to support, the differing needs of the Defence and National Security space R&D ecosystem. **Connected and Collaborative:** Connect people and facilitate collaborative and coordinated partnerships between Academia and Industry (incl Defence and international) to further Defence and National Security Space Requirements. Should address high-risk/high-payload opportunities that exploit synergistic strengths within out partner network. **Differentiated:** Internationally competitive with a focus on national strengths, including basic science and disruptive technologies, not playing catch-up **Digitally Engineered:** Use next generation "digital engineering" approaches to understand opportunities and evolve solutions more rapidly. **Dual-use (Commercial):** SmartSAT will support programs which generate technology that can be adapted to other markets, and which has commercial applications which works to grow the viability of Australia's space industry. **Infrastructure:** Create R&D efficiencies through access to highly specialised space related infrastructure and personnel. **STEM/Workforce:** SmartSat will work with Academia to support and focus national STEM education and training goals and leads on the targeting and coordination of space research education and specialist skills development programs, pursuing where feasible the creation of centres of excellence, that enables the generation of space related programs that have the critical mass to be economical and sustainable. **Value-for-Money:** Access to ongoing lines of funding to secure and sustain Australia's space focused R&D supporting the Defence and National Security sector.			

Optical and Radio Communication SWOT

Strengths	Weaknesses

• Easy to acquire and point to a satellite
• Tradeable Size, Weight and Power (SWaP)
• Capacity scales with physical aperture (small to large)
• Highly robust to ‘all weather’ (<10GHz)
• Mature / available technology / standards
 	
• Hard to Contest
    • Narrow beams ↣ narrow field of view receivers
    • Hard to intercept and jam
• High capacity
	• Contestable – wide beams, susceptible to interference, easy to intercept
	• High capacity requires large antennas
	
	• Very difficult to acquire and maintain pointing
	• Fragile in some common weather scenarios (clouds)
	• Currently requires exquisite technology
	• Large stabilized ground terminals
	• Communications technologies and standards less mature than RF counterpart

Opportunities	**Threats**
• Frequency band diversity • Basis for Quantum Security methods (Incl. QKD) • Large Spectrum availability – Medium to High Capacity • Current investment is maturing technologies • Market demand for bandwidth	• Congestion – finite spectrum availability / increasing demand • Uncertain Regulatory Environment

Coherent Optical Free Space Communications

Overview: Four-year project to develop a system that will enable internet-like data transfer rates (>1 Tb/s) for space-to-ground communication.

Demonstrated over free-space laser links between buildings and via drones and planes as a stepping-stone towards a satellite-based system.

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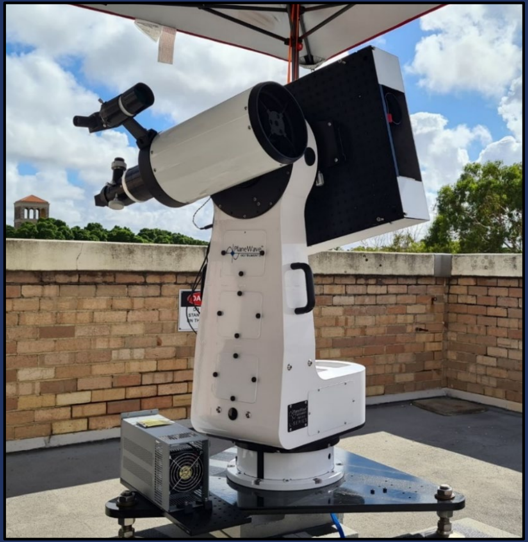
ThalesAlenia Space a Thales / Leonardo company

University of South Australia

GOONHILLY EARTH STATION

Australian Government Department of Defence Science and Technology

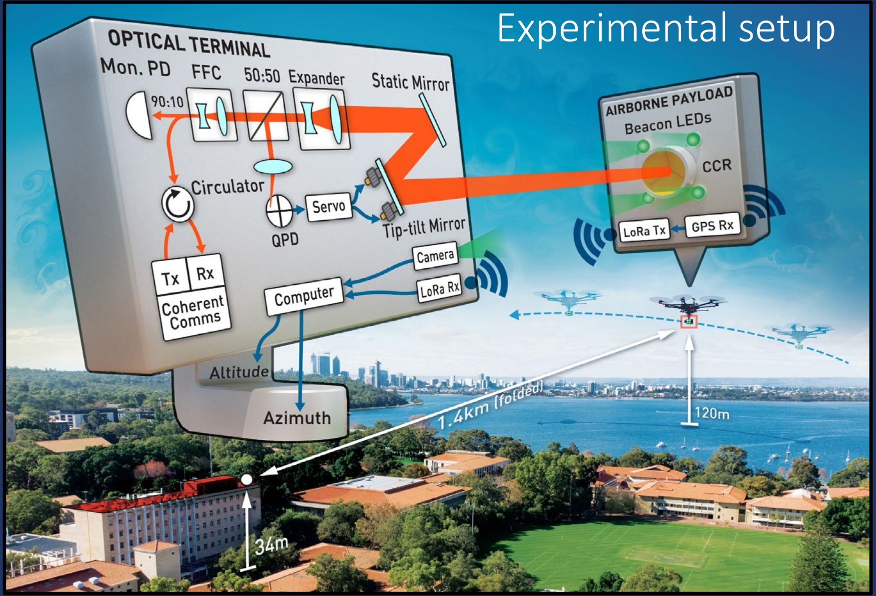
Recent Highlight: Coherent Data-link to Drone Emulating LEO Satellite

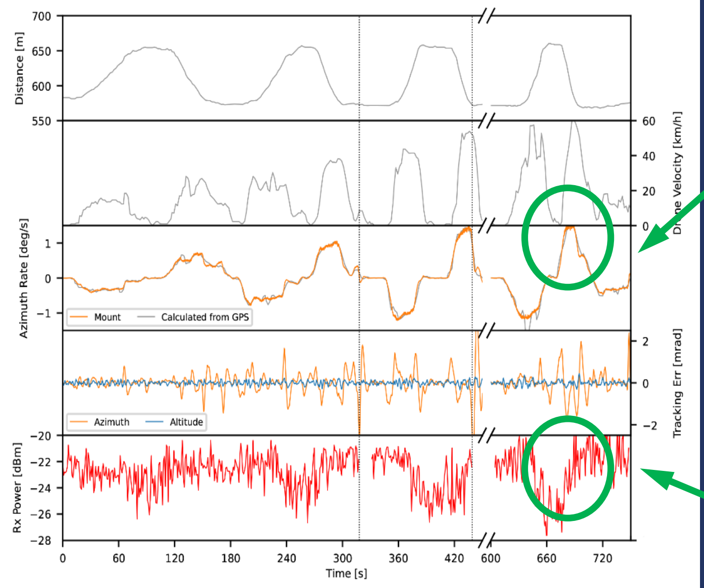


Transportable optical terminal

Active drone acquisition and tracking

Recent Highlight: 100 Gbps Sustained Data Transfer





LEO transit speeds

Robust single-mode fibre coupling

More information: Walsh et al. Sci. Rep. ***12****, 18345 (2022) www.nature.com/articles/s41598-022-22027-0*

Compact Hybrid Optical-RF User Segment (CHORUS)

Status:

Phase 1: ‘Feasibility Investigation’ : Complete

- *Value: $540k cash + $740k in-kind == $1.28m*
- *Outcome:* ***<u>Concept is analytically feasible</u>***

Phase 2: ‘Engineering Model’ (18 months)

- Value: $1.28m cash and $1.56m in-kind == $2.85m
- July 2021 to <u>April 2023</u> : ***Underway***

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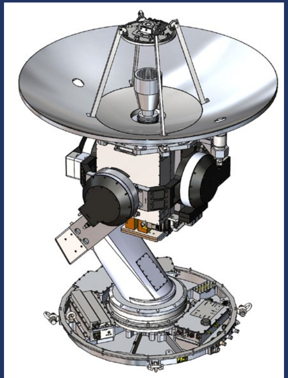

EM SOLUTIONS Radio waves at work
EOS ELECTRO OPTIC SYSTEMS
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Australian National University
UniSA
Australian Government Department of Defence Defence Science and Technology Group

CHORUS Target Function and Performance

Orbit

- LEO (elevation >15 degrees), MEO and GEO

Data Rates (typical)

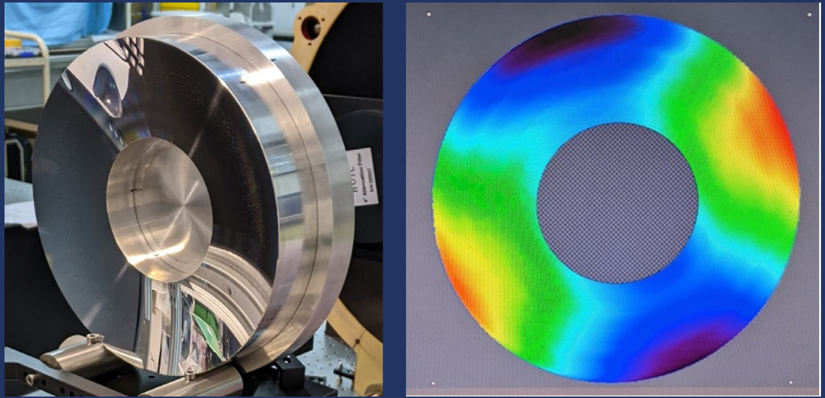
- RF 1-5Mbps
- Optical
  - Earth-space: 0.1-5Mbps
  - Space-earth: 100Mbps

Frequency/Wavelength

- RF
  - U/L 7.9-8.4GHz,
  - D/L 7.25-7.75GHz
- Optical
  - 1550nm (+/- delta)
  - (1064nm)

Aperture

- RF: 1.1m
- Optical: Rx = 460mm, Tx = 2 @ 50mm



Left: Diamond turned 300 mm diameter mirror for testing. (93% reflectivity)
Right: Interferogram of mirror surface with < 1.3 μm (PV) surface quality

CHORUS Planned Outcomes from Project

On track to demonstrate CHORUS over terrestrial path in Q1 2023

Key lessons

- Simple approach to optical receiver
- Re-connecting engineering and physics

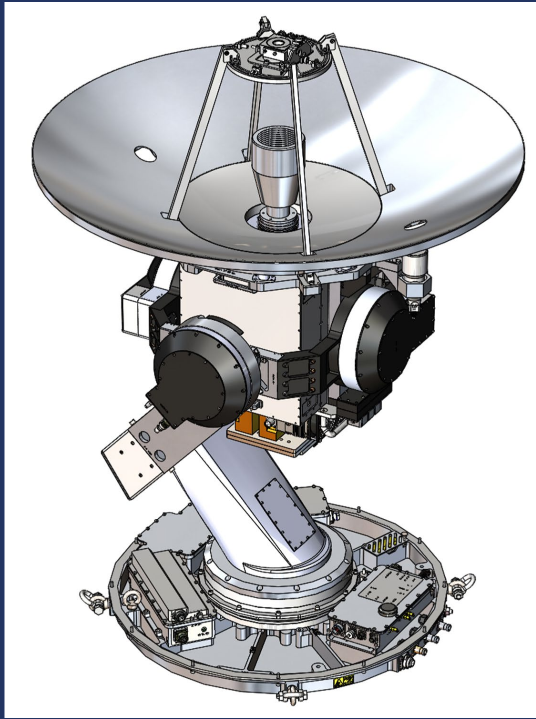
Space Demonstration Opportunities

- Defence Resilient Multi-mission Space STaR Shot

MBSE supporting early stage research

Land Environment

- Potential for Ka band and smaller RF aperture



Hybrid Optical/E-band Correlated Channel Model

Project aimed to understand channel diversity for Optical/RF hybrid communications at mm Wave frequencies

DSTG funded access to industry dataset

- Commercial communications links
- Concurrent bidirectional terrestrial LOS transmission
- Optical and E-band communications on a near coincident path.
  - E-band = 73.5/83.5 GHz; Optical = 193.5 THz

Dataset captured at a number of locations around the world accompanied by weather observations of varying fidelity

Opportunistic dataset - no possibility of 'designing' the experiment

Australian Government
Department of Defence
Science and Technology

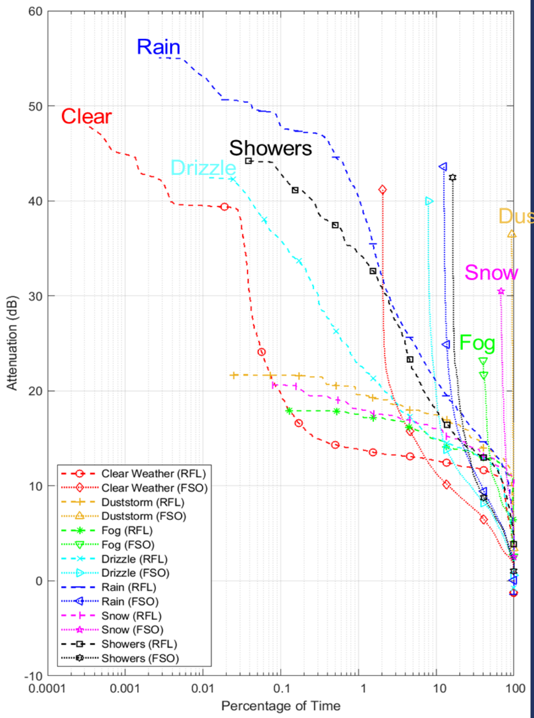
THE UNIVERSITY of ADELAIDE

Principal Researcher: Dr. Siu-Wai Ho (Teletraffic Research Centre, University of Adelaide)
Project Lead: Dr. Gerald Bolding (DSTG)
Contributors: Mark Stewart, Vince Wang, Andre` Costa, Lewis Mitchell (University of Adelaide)

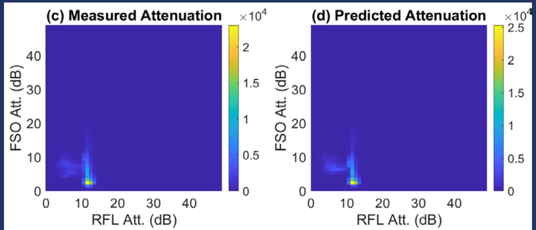
Hybrid Optical/E-band Correlated Channel Model

For <u>this</u> Data Set

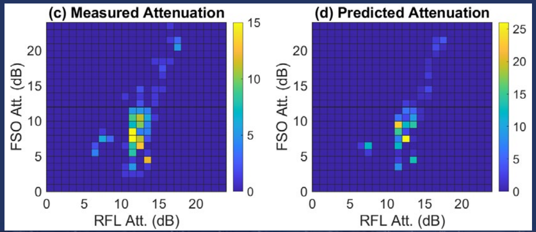
- Dust, Snow and Fog have much more significance for FSO
- Rain, Drizzle and Showers appear to have more ‘equal’ impacts on both FSO and RFL
- From the data labelled ‘Clear’, it appears there are other factors affecting the links
- Potential factors could include scintillation (FSO), equipment issues and mis-pointing



<u>Clear Weather</u>



<u>Fog or Ice Fog</u>



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Towards a Federated QKD System

Jointly funded project under Australia-UK Space Bridge Program

Develop Australian optical communications ground stations to access Arqit's QuantumCloud™

Creating opportunities for Australia to join international partners for commercial quantum key distribution

Support industry access to quantum technology supply chains for space-based infrastructure

Potential to extend this initial project through the iLAuNCH Trailblazer

User Informed • Industry Driven • Research Powered

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