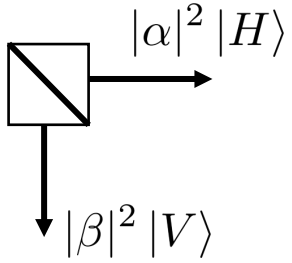
Quantum Time Transfer

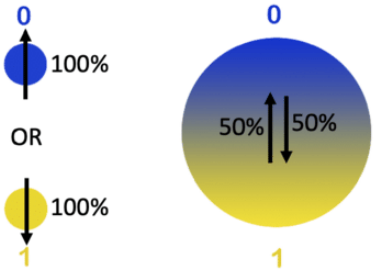
Quantum Technology Overview

The Foundations of Quantum Mechanics

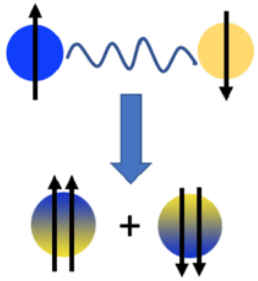
Observables and Measurements



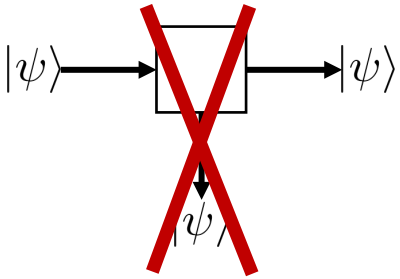
Superposition



Entanglement



No-cloning



The Second Quantum Revolution

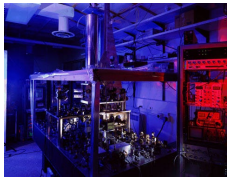
Quantum Mechanics

1900 - 1950

First Quantum Revolution

1950 – 2000s

Second Quantum Revolution



Today

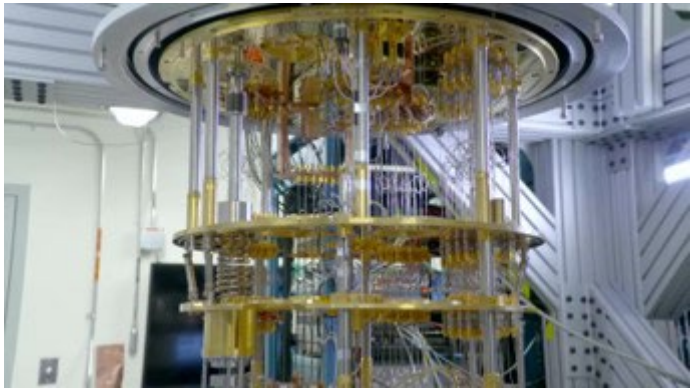
Quantum Computing

Quantum Technologies

Quantum Computing

Quantum Communications

Quantum Sensing



Quantum Sensing

Quantum Technologies

Quantum Computing

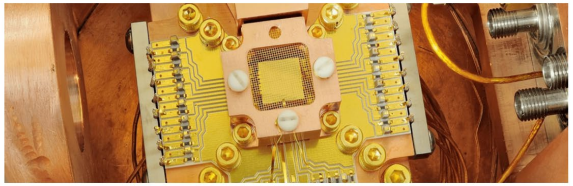
Quantum Communications

Quantum Sensing

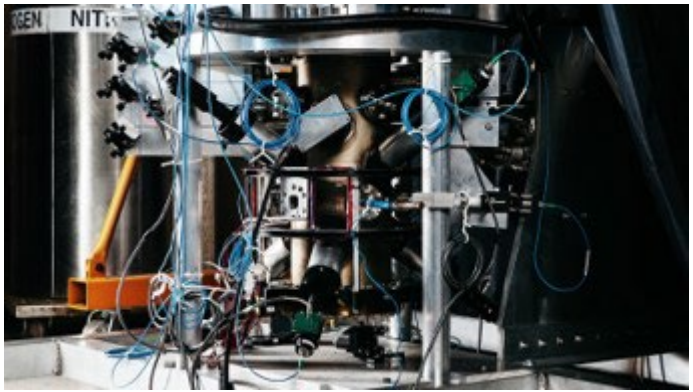
The Quantum Future of PNT

After a 20-year run as the undisputed king of navigation, GPS may soon receive help from emerging quantum applications

By: Andrew Foerch | July 23, 2018



When ambitious researchers tout quantum information science (QIS) as the driver of the next technological revolution, they're usually referring to quantum computing as it applies to rapid data analysis and deciphering encryptions. But quantum's first major disruption may actually come in the realm of positioning, navigation, and timing (PNT).



Quantum Communications

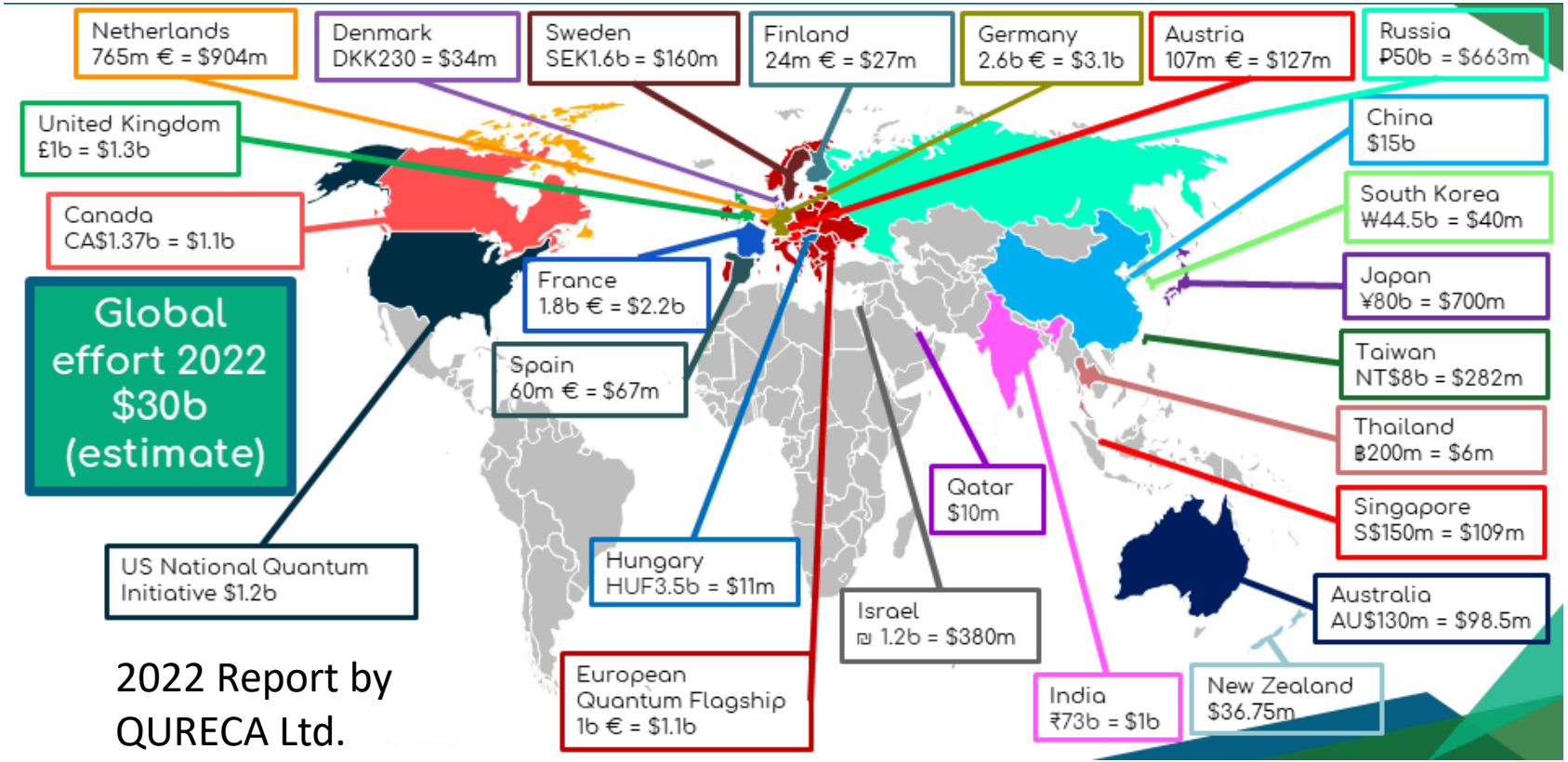
Quantum Technologies

Quantum Computing

Quantum Communications

Quantum Sensing

Quantum Efforts Worldwide



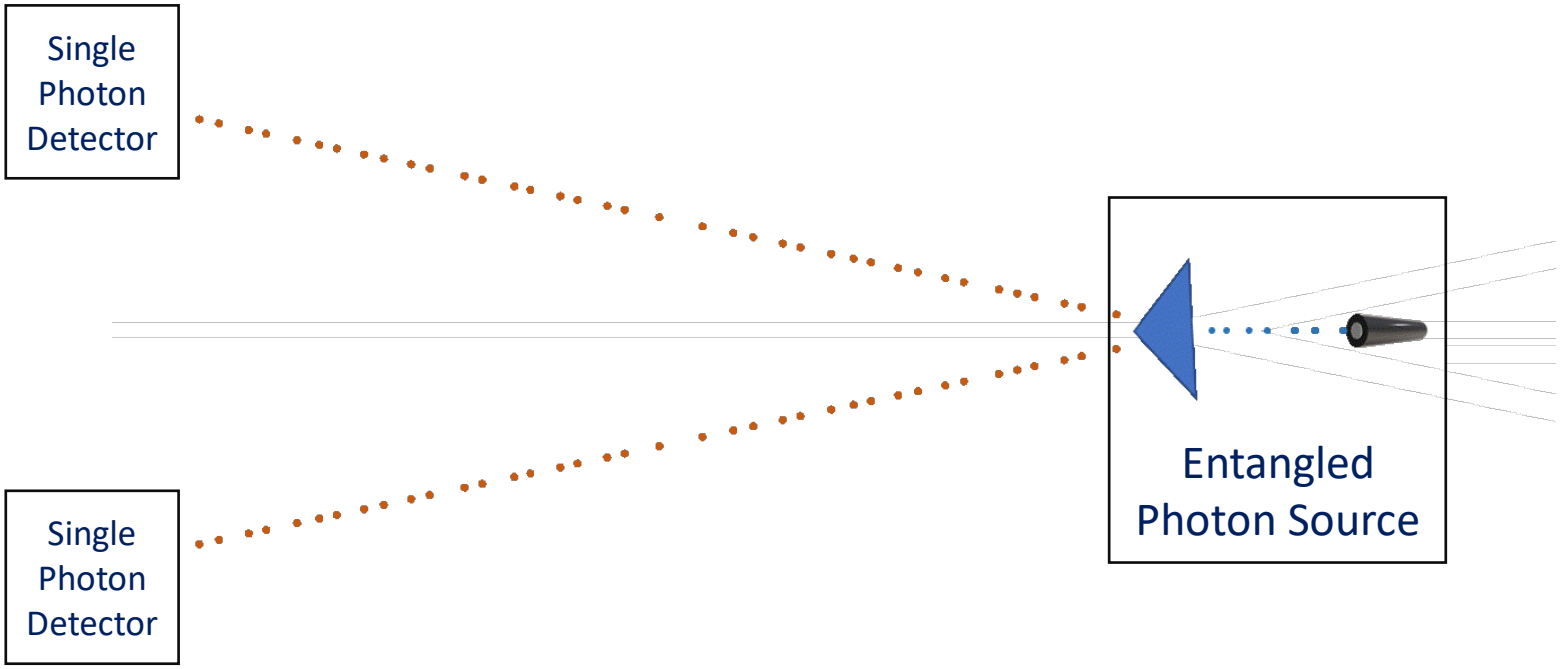
2022 Report by QURECA Ltd.

Quantum Communications

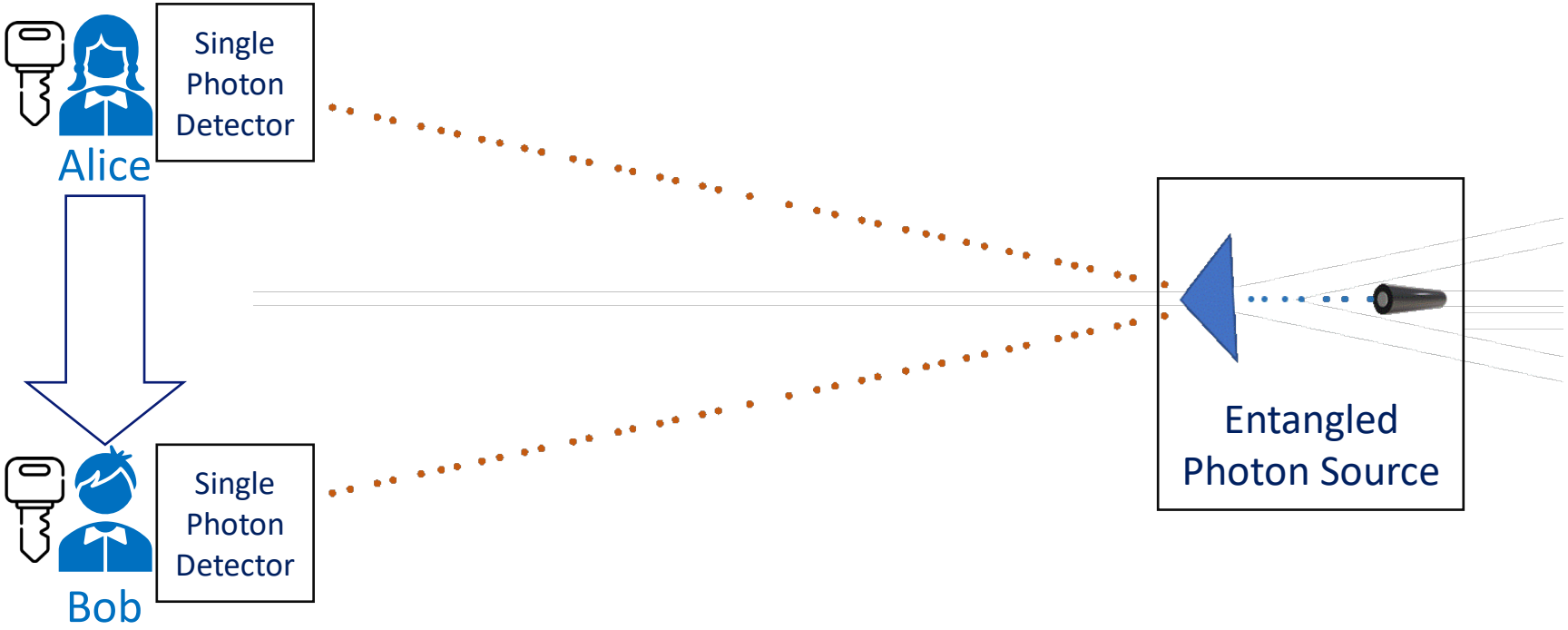
Optical Communications

Quantum Communications

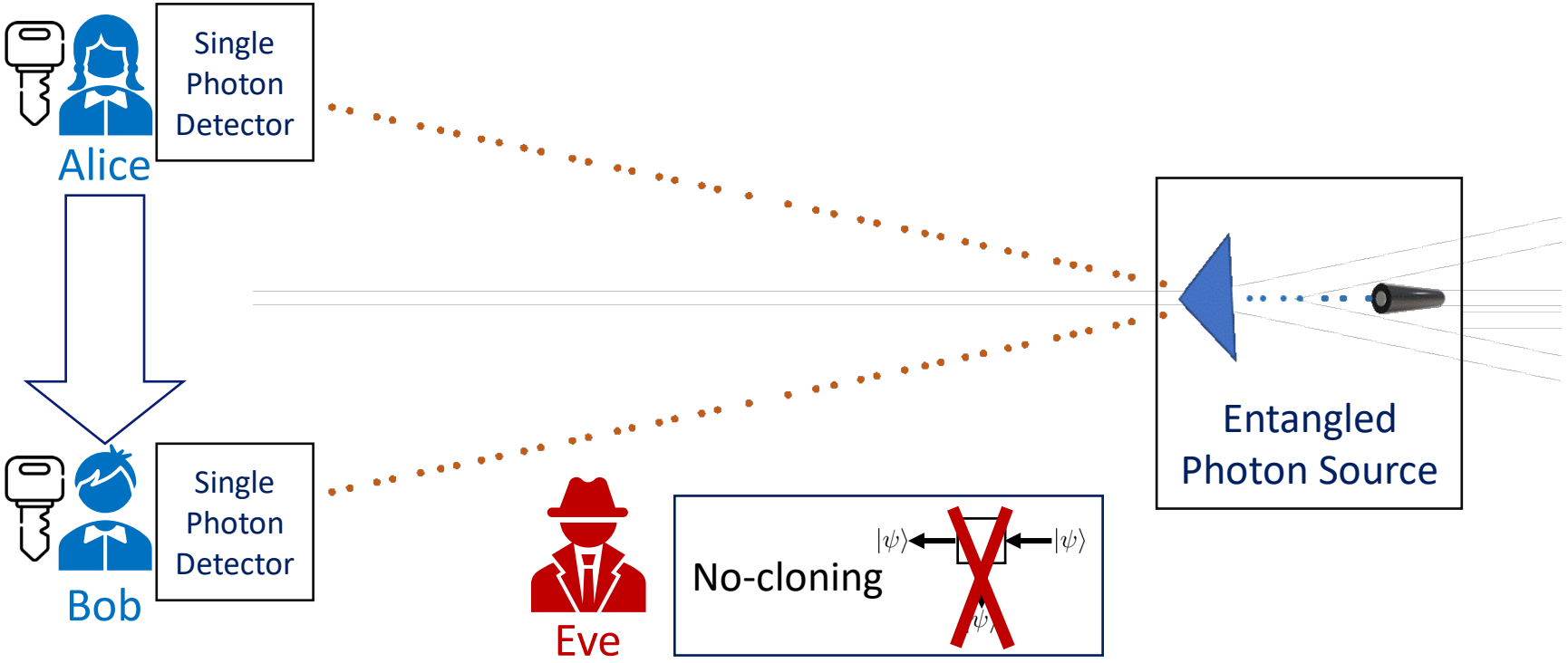
Entangled Photons



Quantum Key Distribution (QKD)



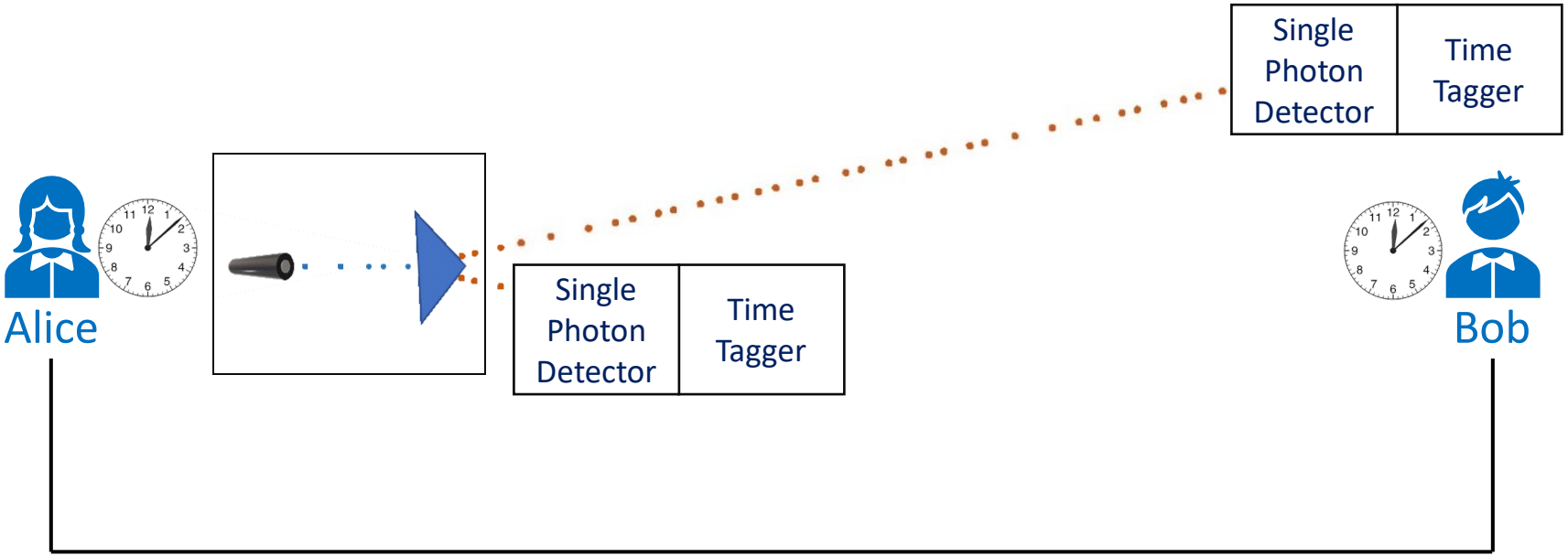
Quantum Key Distribution (QKD)



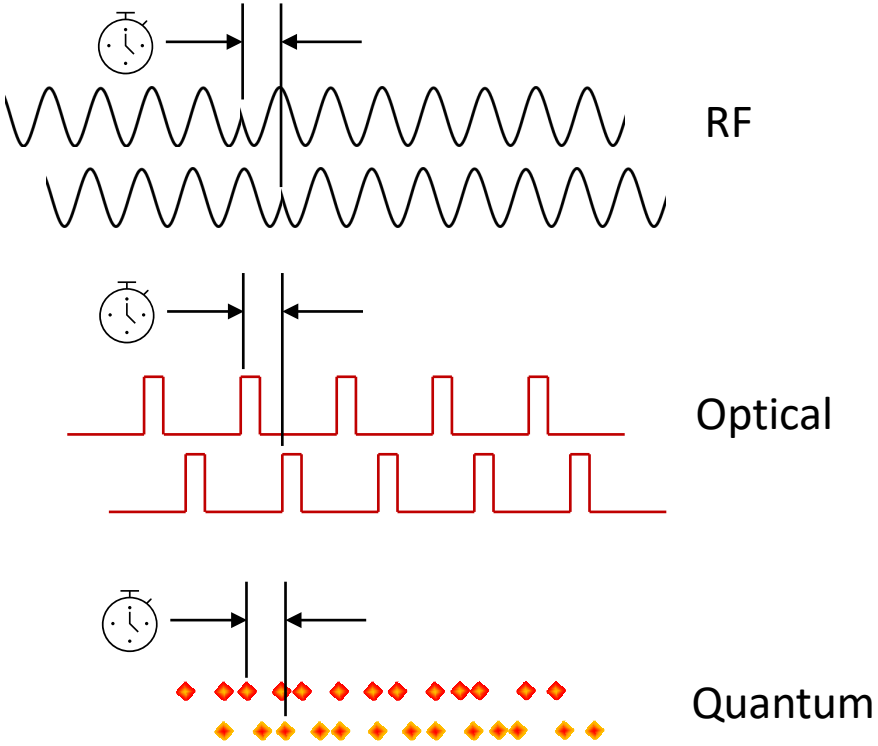
Quantum Time Transfer

Quantum Time Transfer – How is it Done?

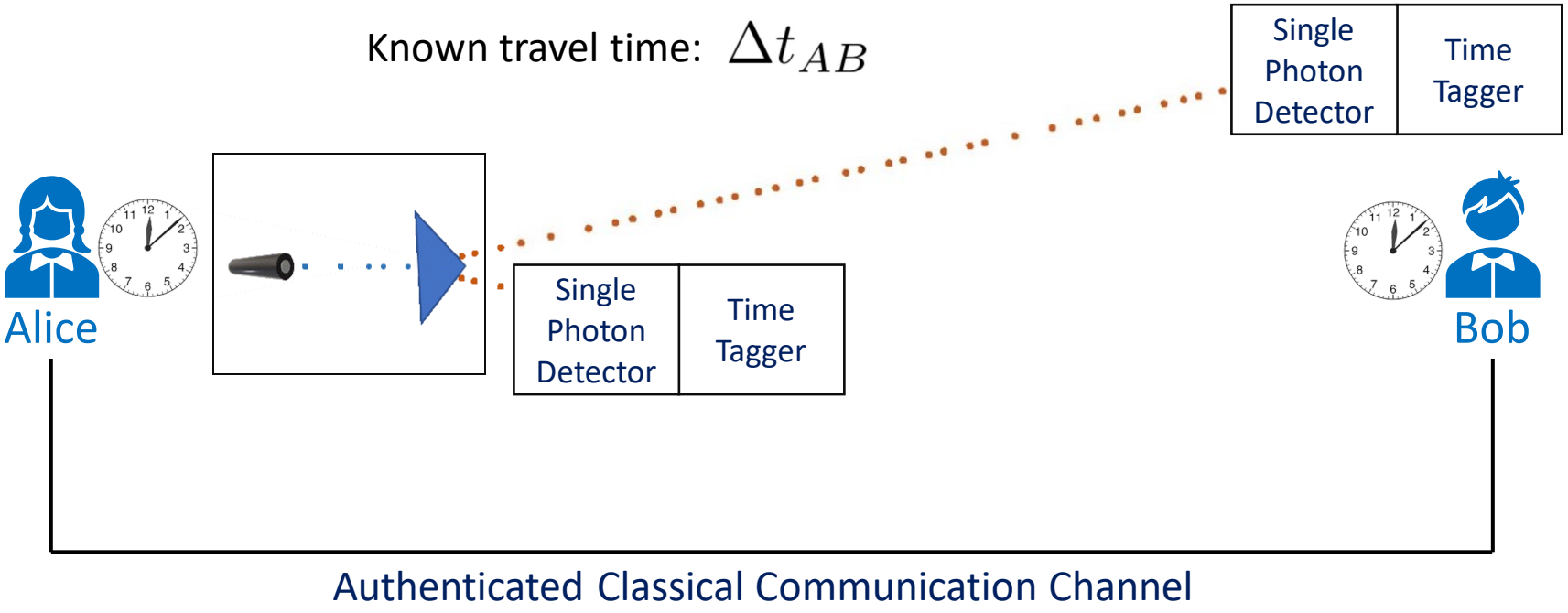
Quantum Time Transfer Overview



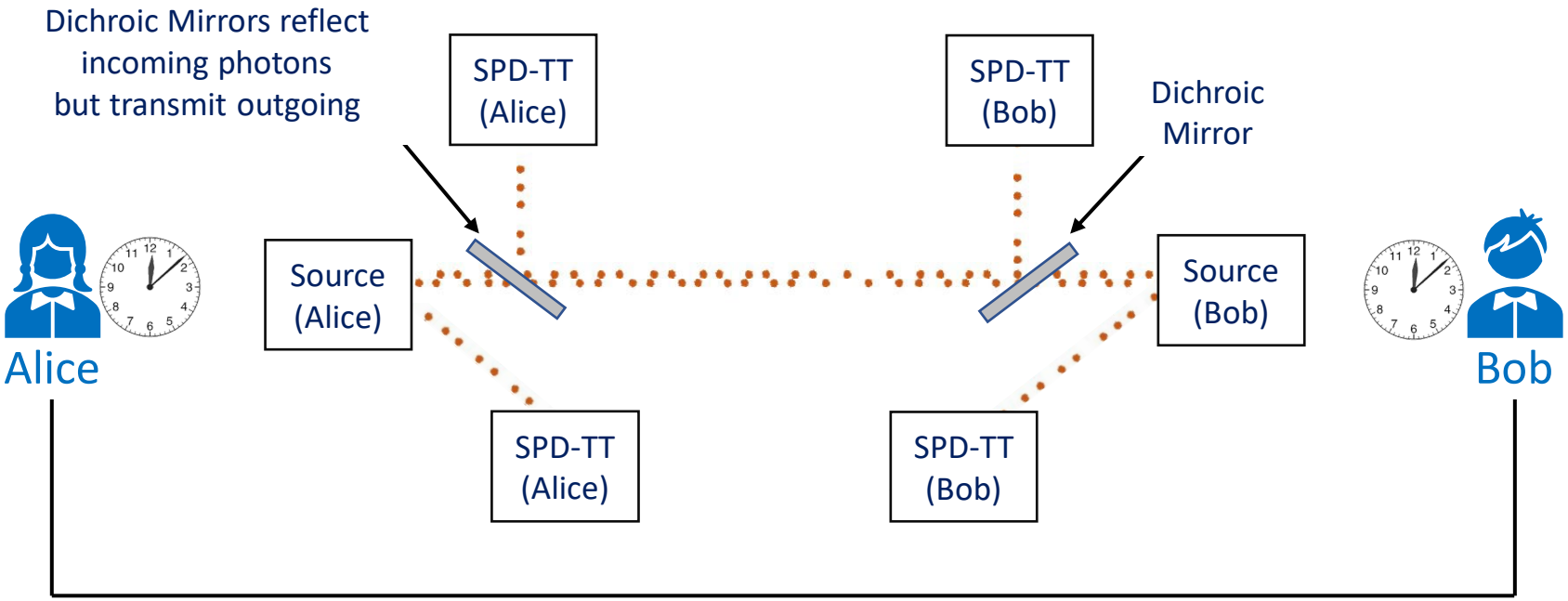
Quantum Time Transfer vs RF and Optical Time Transfer



Quantum Time Transfer - One-Way Setup



Quantum Time Transfer - Two-Way Setup



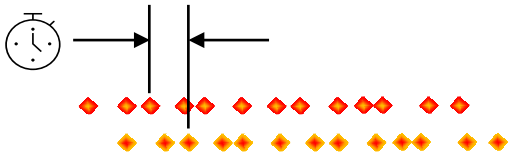
Quantum Time Transfer - Two-Way Protocol

Alice and Bob create entangled photon pairs and send them to each other

A & B detect photons and store timestamp information

Alice & Bob exchange timestamp data through an authenticated classical channel

A & B use time correlations between received and detected timestamps to determine clock offset

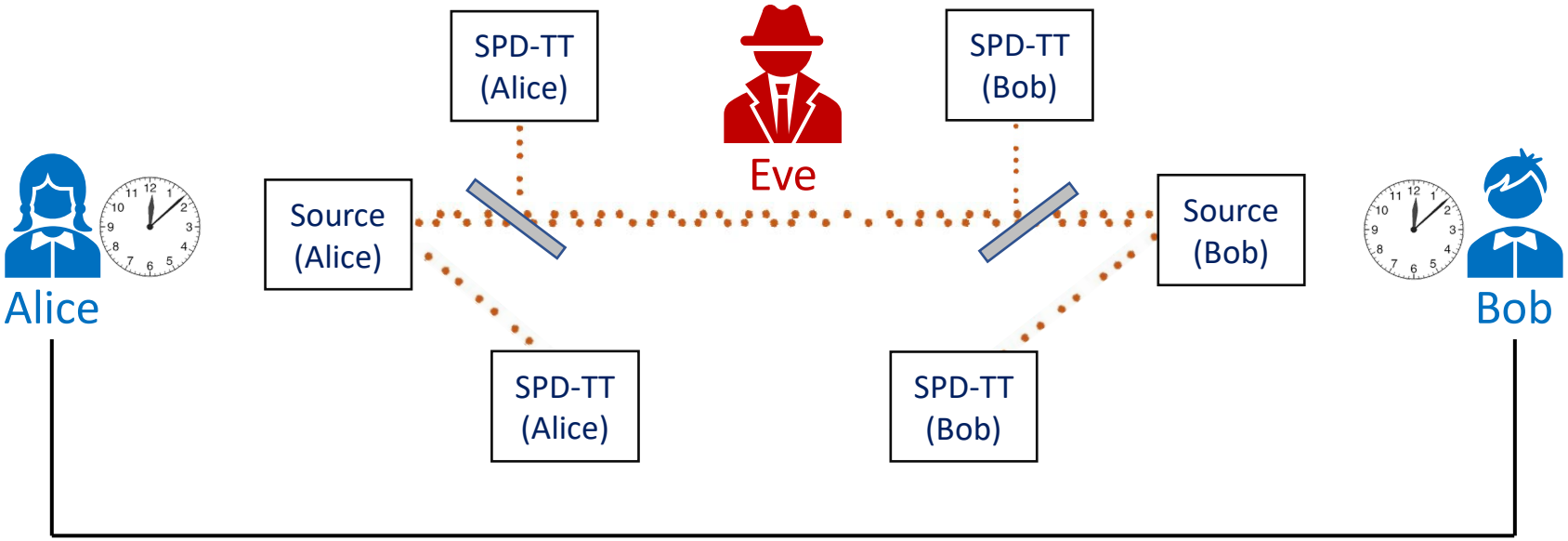


A & B use clock offsets to synchronize their clocks

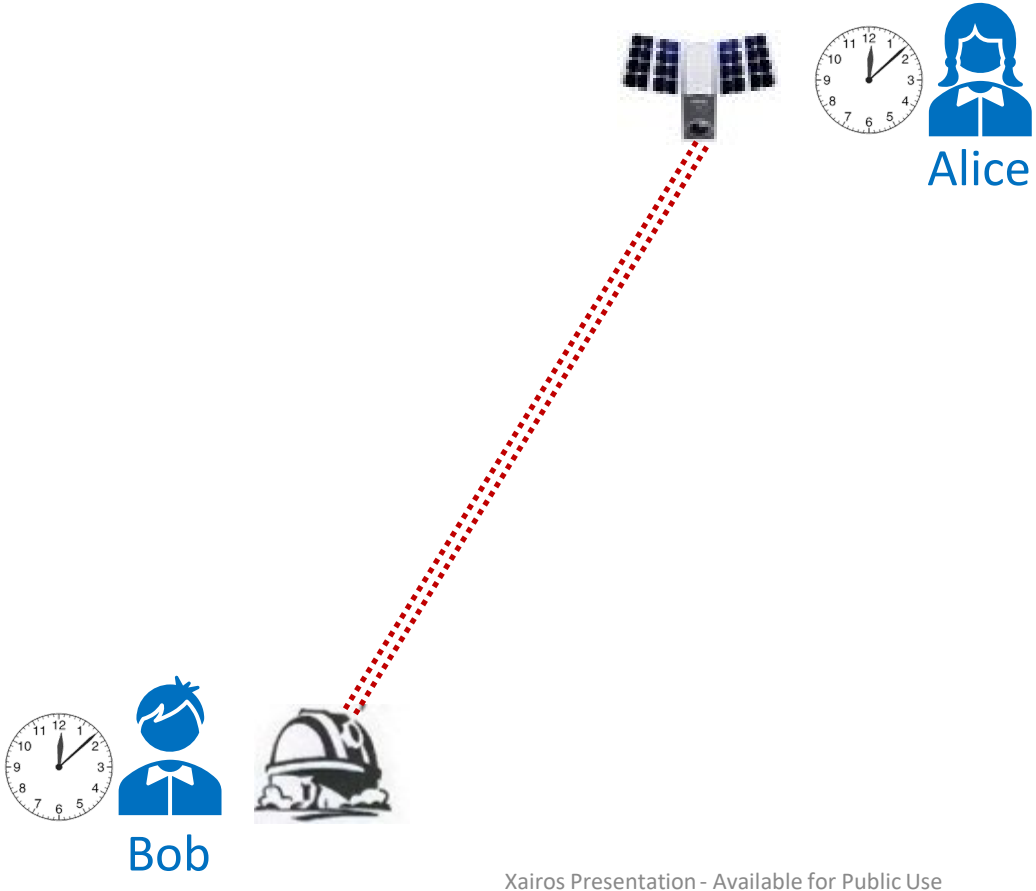
Quantum Time Transfer - Security

Entanglement and no-cloning provide security

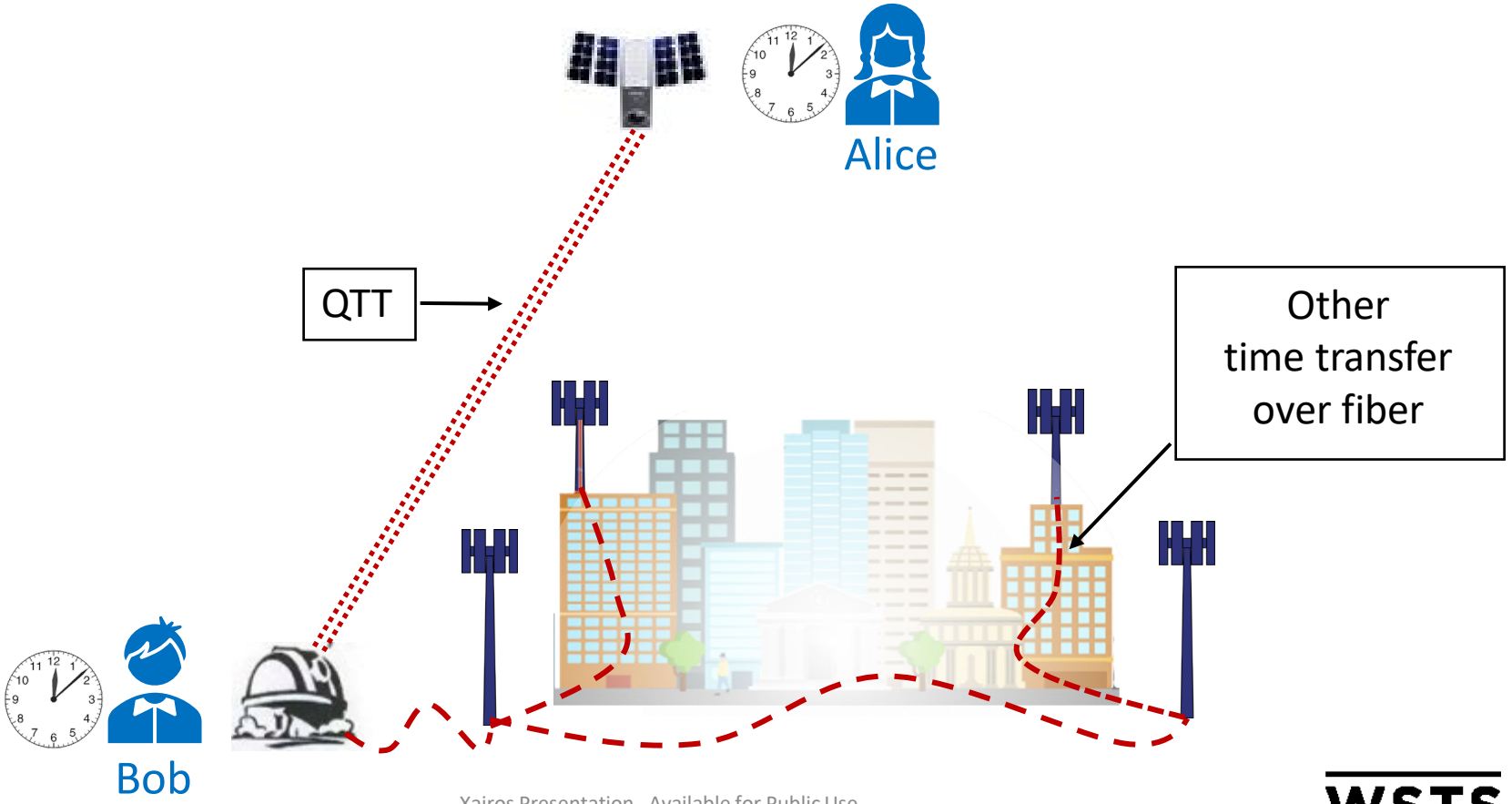
The integrity of the clock offset measurement is protected against attacks.



Quantum Time Transfer over Satellite

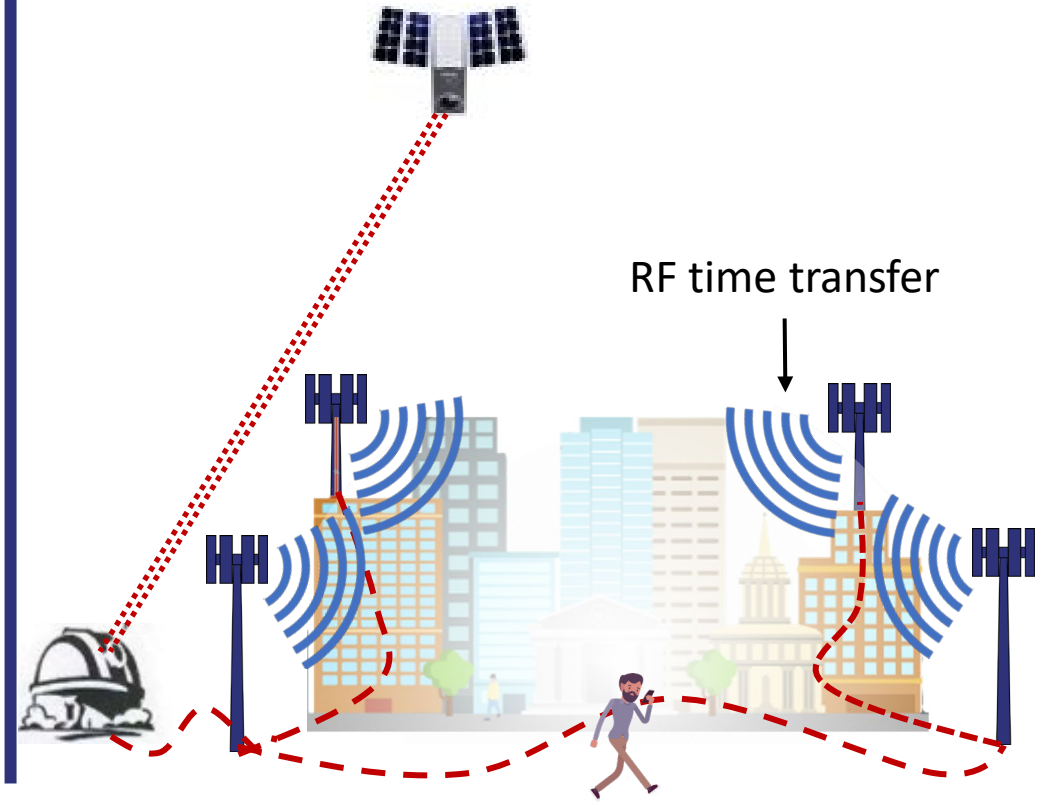


Time Distribution via Quantum Time Transfer



Time Distribution via Quantum Time Transfer

GNSS



WSTS

Quantum Time Transfer – Development Efforts

QTT Development Efforts

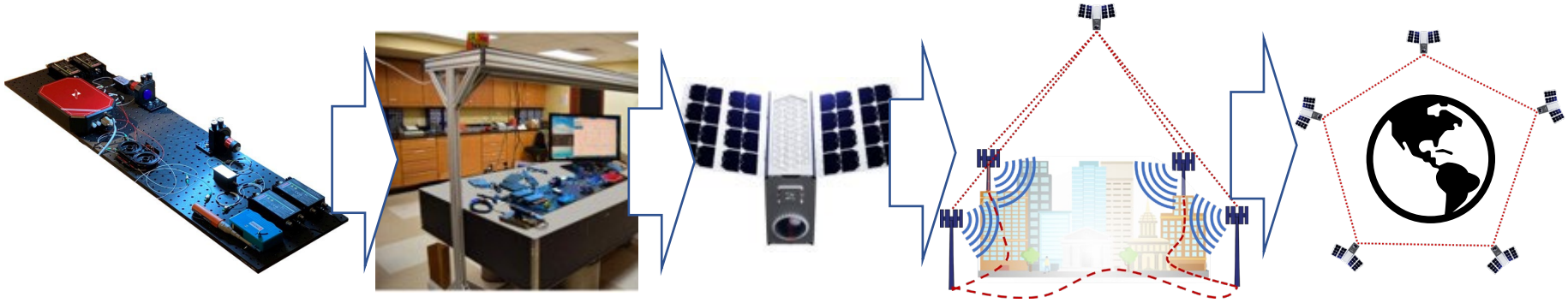
Xairos Systems, Inc.		• Company focused on satellite-based Quantum Time Transfer. • A two-way quantum time transfer protocol with authentication of timing signals using polarization entanglement. • Have performed detailed simulations and proof-of concept experiments for static links. • Are developing simulation and experiments for dynamic links for satellite based QTT.
QuantX Labs / University of Adelaide		• Atomic clock and quantum sensor company. • Recently performed simulations and early experiments using one-way protocol with correlated photons.
Fraunhofer Institute for Applied Optics and Precision Engineering		• Simulations and early experiments using one-way protocol with correlated photons • **Static** one-way link between relatively low stability clocks, using Si APDs. • No quantum authentication demonstrated. • https://doi.org/10.1364/CLEO_AT.2022.AW5P.4 and arXiv:2108.13466

QTT Development Efforts

Hefei National Laboratory - Micius Satellite		• QKD and quantum science satellite in orbit. • Experimentally demonstrated feasibility extraction of photon pair correlation from a one-way satellite-to-ground quantum link, augmented with classical laser uplink for range estimation. • No quantum authentication demonstrated. • https://doi.org/10.1364/OPTICA.458330
National Time Service Center		• Two-way protocol with time-frequency entangled photon source. • Experiments over 7-km fiber link between H-maser and Rb clocks. • **Static** two-way links, demonstrated a TDEV of 1.9 ps at 30 seconds, used superconducting nanowire single-photon detectors. • No quantum authentication demonstrated. • https://doi.org/10.1364/OE.451172

Quantum Time Transfer – Xairos Development Plans

Towards Global Picosecond Level Accuracy



Proof-of-Concept | Testbed | Satellite | Local Service | Global Service

Quantum Testbeds

CHICAGO QUANTUM EXCHANGE

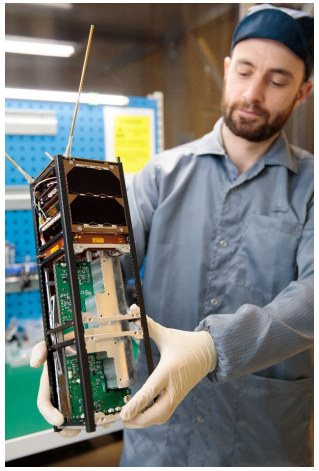
Testbed

epb Quantum Network

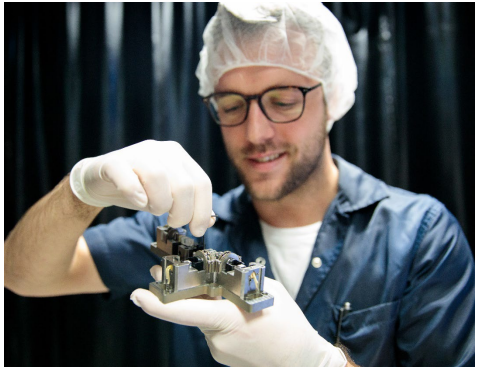
NRL Announces the Washington Metropolitan Quantum Network Research Consortium (DC-QNet)

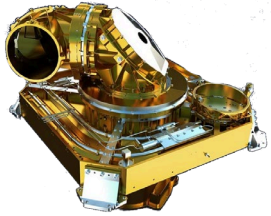
By Paul Cage, U.S. Naval Research Laboratory Corporate Communications

Quantum Timing Satellite



Satellite





Thank You!

Any Questions?