

An Overview of the UK National Quantum Technologies Programme

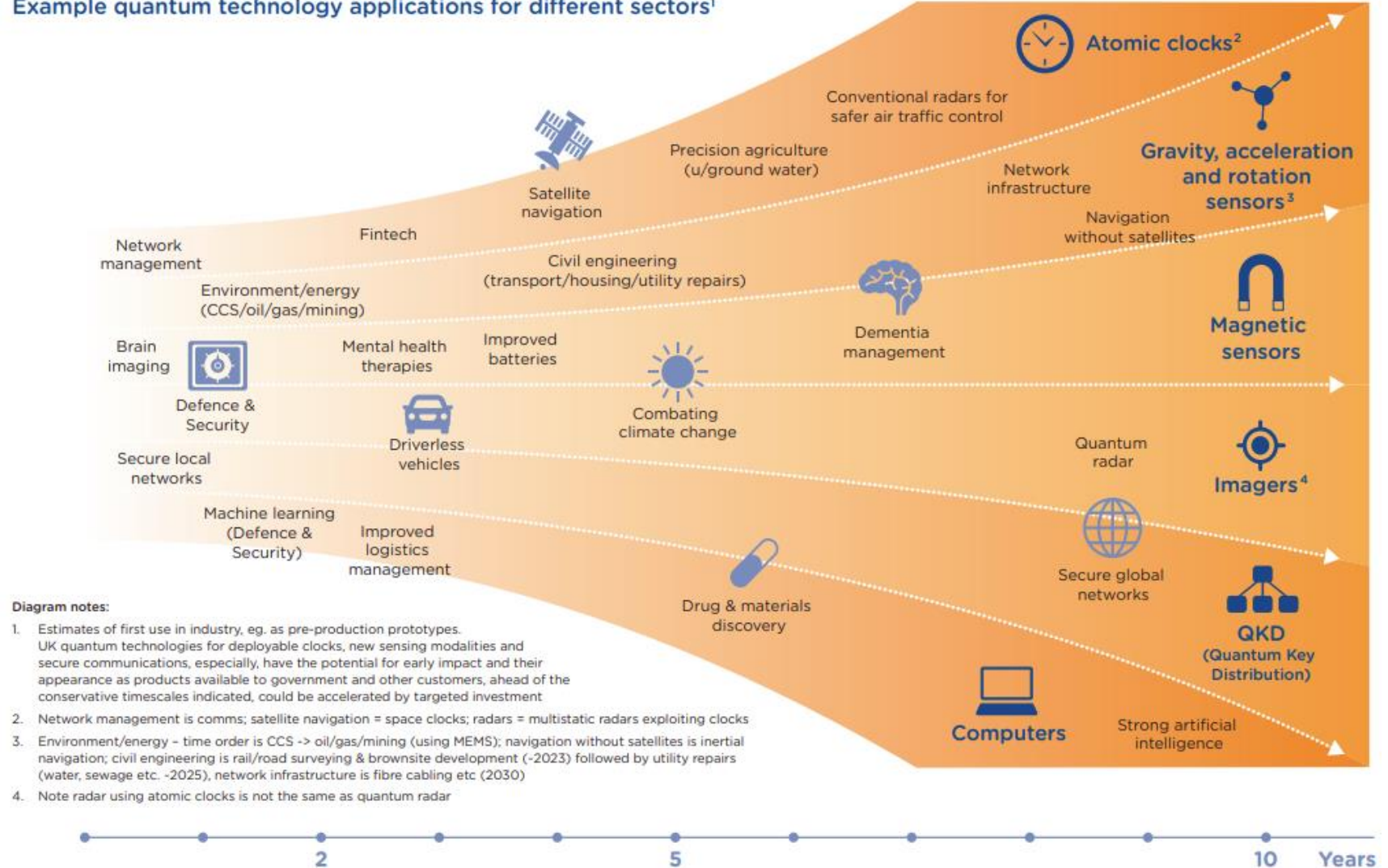
September 2022 - Glasgow

Roger McKinlay – Challenge Director, Commercialising Quantum Technologies Challenge. Innovate UK.

Why does Quantum matter?

- Transformative change across a number of sectors.
- Computing
- Secure communication
- Sensing and timing - PNT
- Imaging

Example quantum technology applications for different sectors¹

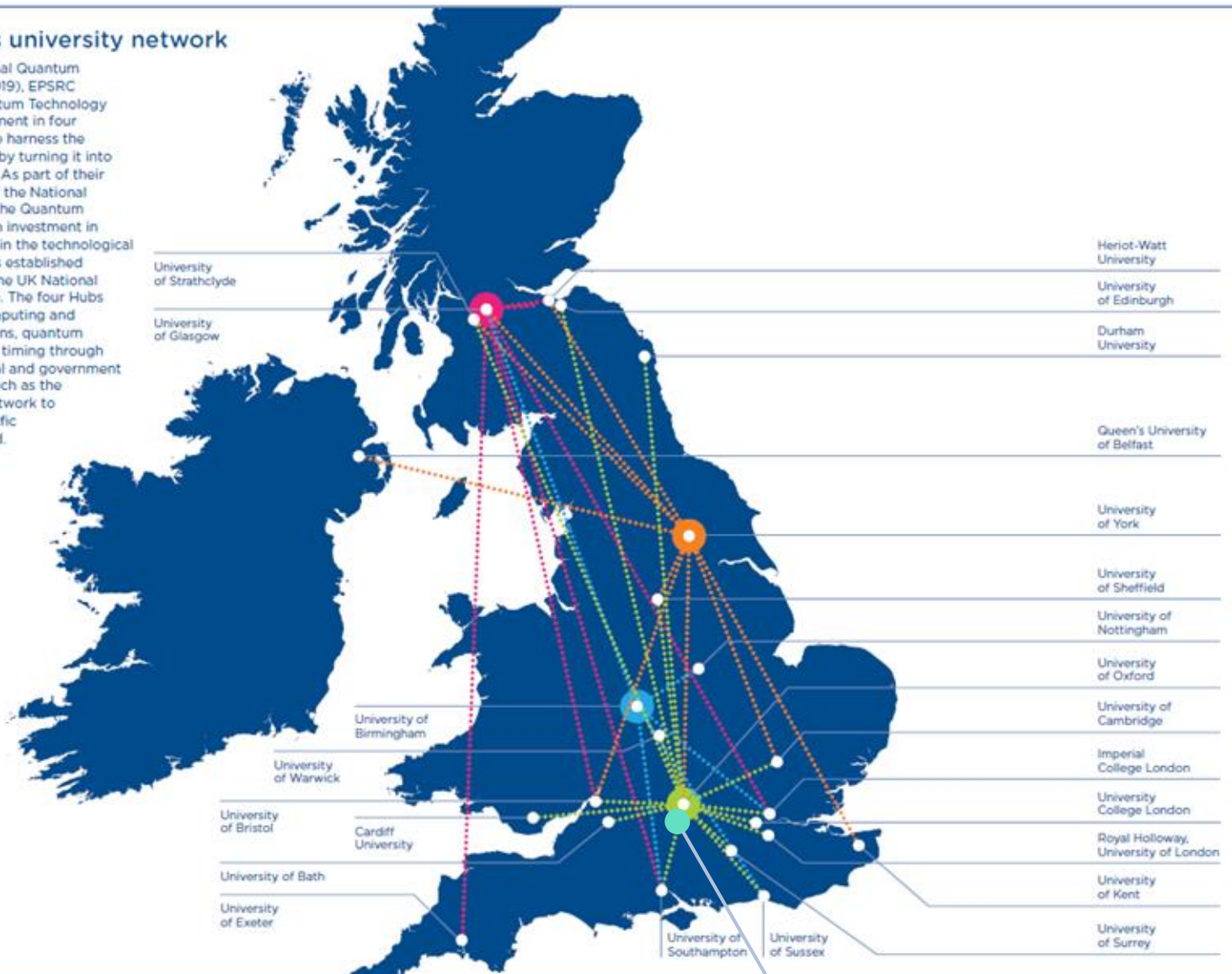


The National Programme – est. 2014

NQTP National Hubs university network

During the first phase of the National Quantum Technologies Programme (2014–2019), EPSRC funded a national network of Quantum Technology Hubs through a £120 million investment in four hubs over five years. These were to harness the UK's strengths in quantum science by turning it into strength in quantum technologies. As part of their investments in the second phase of the National Programme, EPSRC has refreshed the Quantum Technology Hubs with a £94 million investment in four hubs over five years, to maintain the technological research leadership that the UK has established in quantum technologies through the UK National Quantum Technologies Programme. The four Hubs focus on the areas of quantum computing and simulation, quantum communications, quantum imaging, and quantum sensing and timing through a wide range of academic, industrial and government partnerships. Other investments, such as the NQCC will interact with the Hub network to extend and capitalise on the scientific leadership that has been developed.

- UK National Quantum Technology Hub in Sensing and Timing
- The EPSRC Quantum Communications Hub
- The UK Quantum Technology Hub in Quantum Imaging
- EPSRC Hub in Quantum Computing and Simulation



125 MSc candidates	>470 PhD candidates
120 Hub industry partners	85 QT Apprenticeships
49 UK start-ups 590 employed	>£245m UK V/C funds raised
>40 UK Quantum Suppliers	£1bn UK public/private investment



ISCF – Bringing in Industry 2018

Audience of the future
(up to £33m)



Early diagnosis & precision
med (up to £196m)



Energy revolution
(up to £102.5m)



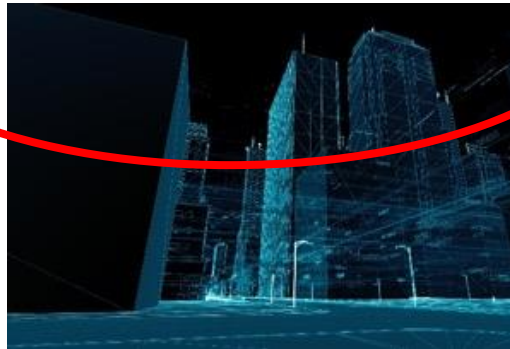
Healthy ageing
(up to £98m)



Next generation
services (up to £20m)



Quantum technology
(up to £20m)*



Transforming construction
(up to £170m)



Transforming food
production (up to £90m)



*Quantum received a further £153M in Wave 3

ISCF Wave 3

WHY ISCF WAVE 3?

System Failures
(Market, Coordination,
Network.)

Investment Risk

Maintain Momentum

International
Competition

OBJECTIVES

Sales of Products
and Services

R&D Investment

Focussed Research

Academic-Business
coordination

WHAT WILL WE DELIVER?

2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
CR&D					
Feasibility Studies					
Technology Projects					
IA					

CR&D

Feasibility
Studies

Technology
Projects

IA

WHAT ARE THE OUTCOMES

Increased R&D investment

Increased skills & knowledge

New product lines & services

Growth in export opportunities

Improved productivity & profitability

SME involvement

HOW MUCH INVESTMENT?

ISCF Wave 3
£153m

Industry matched funding
£205m

The Benefits We're Seeking.

Reference	Name
B1	Increased investment into Quantum R&D - Public, Private & Foreign
B2	New products and services in the scope of the ISCF
B3	Increased multi/inter- disciplinary QT collaborations
B4	Increased QT business - academic engagement
B5	Increased number of QT publications in peer reviewed journals
B6	Number of start-ups & spin-outs for commercialising QT
B7	Skilled high value workforce to develop & commercialise Quantum technologies
B8	Increased number of QT patents by UK businesses
B9	Increased productivity & profitability for users of QT products / services
B10	Increased size of the sector
B11	Greater market share of global QT market
B12	Increased revenue of QT enabled products & services
B13	Increased revenue of QT products/services by UK QT Organisations

Over £150M Committed to Industry Led Consortia

249 companies
and 57
universities/RTOs
applied for ISCF
Funding

£153M of grants
awarded

95 projects
launched

123 businesses and 38 universities and RTOs are currently active in projects.

Stop Press!
40+ Feasibility Studies

The Quantum Challenge in UKRI: Who receives funding?

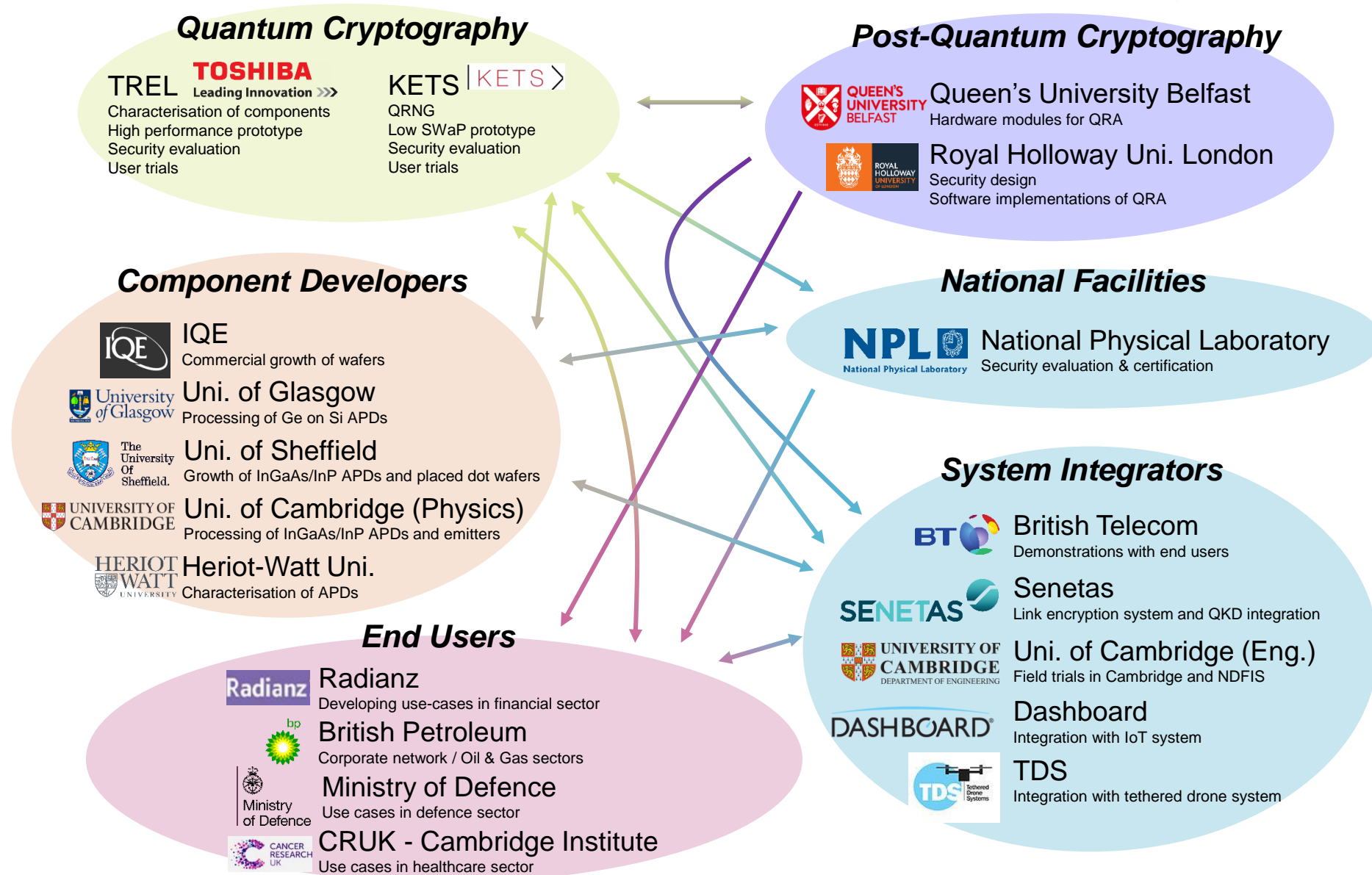
A snapshot of the major grant recipients in December 2021, each receiving between £1M and £6M in grants.



Organisation
FRAUNHOFER UK RESEARCH LIMITED
NPL MANAGEMENT LIMITED
TOSHIBA EUROPE LIMITED
UNIVERSAL QUANTUM LTD
RIGETTI UK LIMITED
SEEQC UK LIMITED
TELEDYNE UK LIMITED
RIVER LANE RESEARCH LTD
Arqit Ltd
OXFORD IONICS LIMITED
NU QUANTUM LTD
M-SQUARED LASERS LIMITED
OXFORD INSTRUMENTS
ALTER TECHNOLOGY TUV NORD UK LIMITED
COLDQUANTA UK LIMITED

^Universities not included

Funding the Glue - AquaSec



A World View: Public and Private Investment



- Public investment: **China** \$15B – **US** \$1.3B – **UK** \$1.2B...
- **Rigetti** expects \$594M **revenue** by 2026
- **Boston Consulting Group** on Quantum Computing: \$450B to \$850B value created in next 15 to 30 years.
- **Hyperion** sizing QC Market: \$490M in 2021. 22% CAGR. \$900M by 2024

FACT BASED INSIGHT Quantum Technology

How will the quantum market evolve?

- Governments are getting geopolitical**
 - China \$15B, EU \$7.2B, US \$1.3B, UK \$1.2B, India \$1B, Japan \$1B,
 - Also Russia, Canada, Israel, Singapore, Australia
- Leading companies are bullish**
 - Tech majors: IBM, Google, AWS investing heavily
 - Honeywell expects Quantinuum sales of \$2B by 2026 (Feb 2022)
 - Rigetti expects \$594M revenue by 2026 (Oct 2021)
 - D-Wave expects \$551M revenue by 2026 (Feb 2022)
 - IonQ expects \$60M bookings by 2024 (Sep 2021)
 - Toshiba targeting 25% of a \$12B QKD market by 2030 (Oct 2020)
- Management consultants are excited**
 - BCG projections on quantum computing (Jul 2021)
 - \$450B - \$850B value created in the next 15-30 years
 - \$90B-\$170B retained by QC providers.
 - \$5B to \$10B could start accruing in 3-5 years.
 - McKinsey projections on quantum computing (Dec 2021)
 - \$300B - \$700B value at stake by 2030 for pharmaceuticals, chemicals, automotive and finance could
 - \$80B value at stake for quantum computing providers.
 - Avasant & NAASCOM encourage India to bet big (Feb 2022)
 - \$310B cumulative value add to the Indian economy by 2030
- Private capital is on the march**
 - 580+ startups listed by QIS Data (Feb 2022)
 - ~\$500M 2022, \$2.8B 2021, \$1B 2020, \$300M 2019 per QIS Data (Feb 2022)
- Tech market research & advisory are taking note**
 - Hyperion sizing the QC market
 - \$490M in 2021, 22% CAGR \$900M 2024 (Q2B 2021)
 - \$320M in 2020, 27% CAGR \$830M 2024 (Q2B 2020)
 - \$280M in 2019
 - Gartner put QC at peak of hype cycle (Jul 2021)
 - "10 more years of hype before it starts delivering value. [But] starting early is the surest form of success"
- Inside Quantum Technology forecasting**
 - QC in Financial Services \$632M by 2028, \$2.2B by 2030 (Jan 2021)
 - Quantum Cloud Services revenues \$850M in 2026 (May 2021)
 - Quantum Processors market \$200M by 2026 (Apr 2021)
 - Quantum Computing market \$2.2B by 2026 (Nov 2020)
 - QKD market \$1.4B 2027; \$3.4B 2030 (Dec 2021)
 - PQC market \$2.3B 2026, \$7.6B by 2030 (Sep 2021)
 - QRNG market \$7.2B by 2026 (Jan 2021)
 - Quantum Networking market \$5.5B in 2025 (Jan 2020)
 - Quantum Magnetometer market \$700M by 2025 (Apr 2020)
 - Atomic Clock market \$710M 2025, \$1B 2029 (Mar 2020)

NQTP: What is the UK doing?

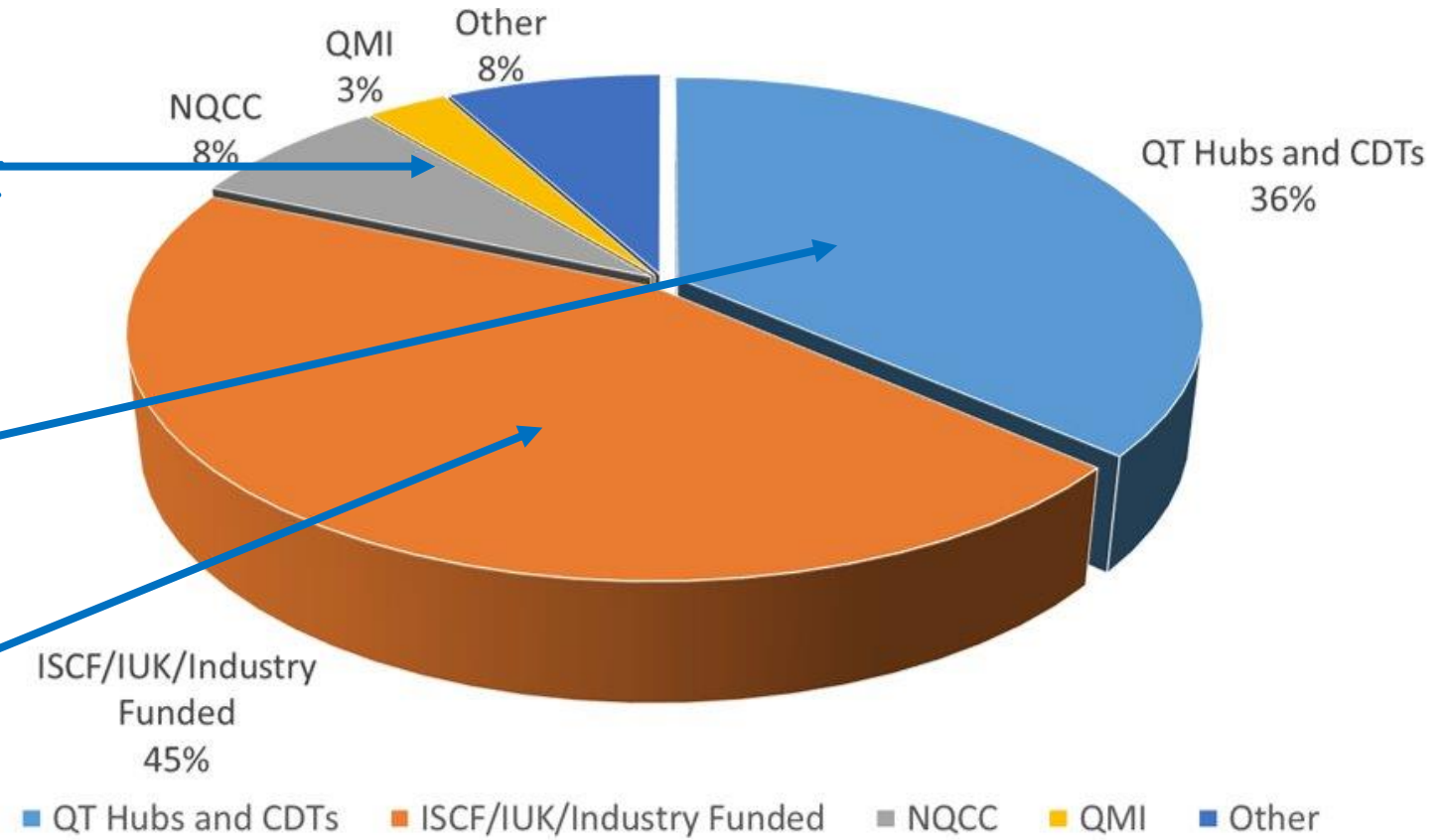
The UK's National Quantum Technologies Programme is a £1bn 10-year investment in the sector.



Infrastructure Bit

Commercialising Science Bit

Collaborative Industry bit



Products

Single photon generation and detection opens the door to imaging systems which cannot be achieved using conventional means, including

- Portable, robust multi-gas imagers for gas emissions in infrastructure
- Vision through obscurance for lidar systems and imaging
- Non-line of sight imaging of obstacles



Single photon lidar imaging of carbon emissions

- Accurate, repeatable, eyesafe measurements at standoff distances of 150m
- Uses mature telecoms technology for affordable and versatile emissions monitoring systems
- Portable and simple to use and export data
 - Heat maps overlaid on visual scene and, with known wind velocities, gives dynamic leak rate data in near-real time
 - Pre-programmable, autonomous measurements for a range of emissions



Hardware and Software

Quantum companies in focus Nu Quantum

Based: Cambridge

Technology chain: Components

Profile:

Start-up. Only company world-wide developing **room temperature single-photon sources** and **detectors** to enable the next generation of commercially-viable photonic quantum technologies, **quantum networking, computing**



Key projects

AirQKD

Assurance for QRNGs

ViSatQT

Computing **●** Comms **●** Sensing & Timing **●** Imaging **●** Components **●**

Quantum companies in focus Riverlane

Based: Cambridge

Technology chain: Software & services

Profile:

Start-up. Builds ground-breaking software to unleash the power of **quantum computers**. Deltaflow.OS is an **operating system** for quantum computers inspired by heterogeneous architectures



Key projects

NISQ.OS

AutoQT

QPharma

Computing **●** Comms **●** Sensing & Timing **●** Imaging **●** Components **●**



ORCA Computing Ltd.

MANATEE

Single photons are the workhorse of the future quantum technology industry, being a fundamental component to high fidelity quantum computing, quantum communications, quantum imaging and some types of quantum sensors. They are also a fundamental step in ORCA's plans to build a fully-scalable, optical fibre-based photonic quantum computing platform...



Computers and Components

Quantum companies in focus

Covesion

Based: Southampton

Technology chain: Components

Profile:

Established SME. World leading designer, manufacturer of frequency conversion crystals – can change the wavelength of laser, single photon sources to suit user specifications or applications



Key projects

MIRUS

QT Assemble

SNORQL

Computing Comms Sensing & Timing Imaging Components



Quantum companies in focus

Alter technologies

Based: Central belt, Scotland

Technology chain: Systems, packaging

Profile:

Large enterprise. package design and precision assembly services for a wide range of optoelectronic, microelectronic and MEMS devices. Offer end to end semiconductor manufacturing from wafer singulation to assembled product.

ALTER
TECHNOLOGY

Key projects

High-BIAS2

QT Assemble

Pioneer Gravity

Computing  Comms  Sensing & Timing  Imaging 

Packaging and Platforms

Quantum companies in focus

Oxford Instruments

Based: Oxford

Technology chain: Component (Platform)

Profile:

Established large enterprise, designs, supplies and supports market-leading cryogenic and high flux superconducting magnetic research platforms. They are a globally **leading supplier** of **dilution fridge** platforms for **quantum computing**



Key projects

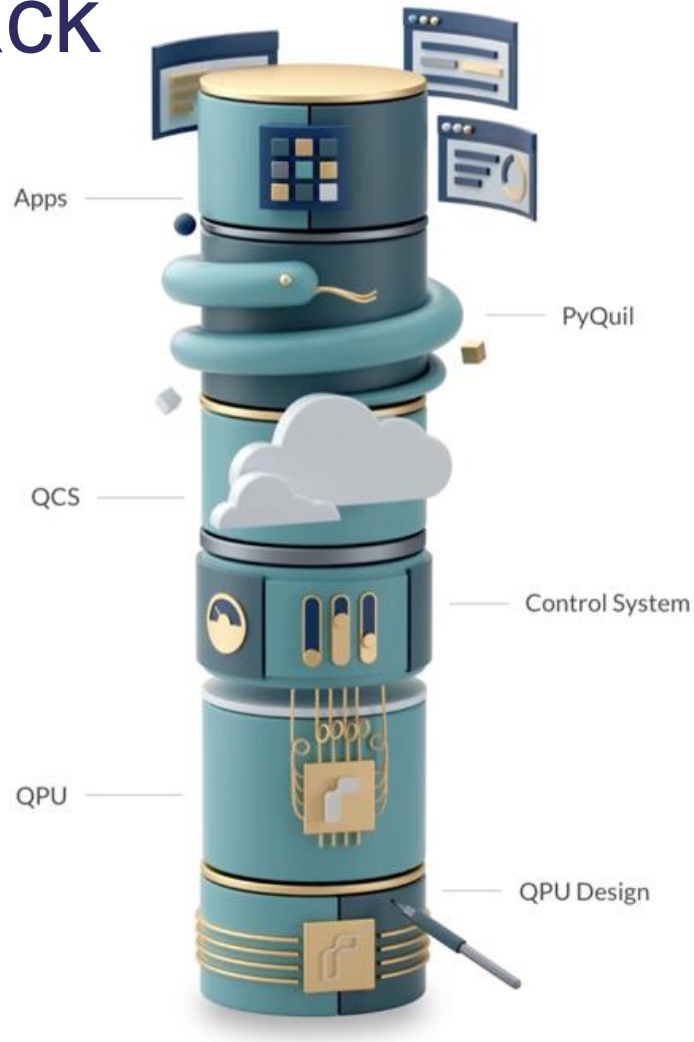
NISQ-Era Platform

FABU

QuPharma

Computing  Comms Sensing & Timing Imaging  Components

Full Stack



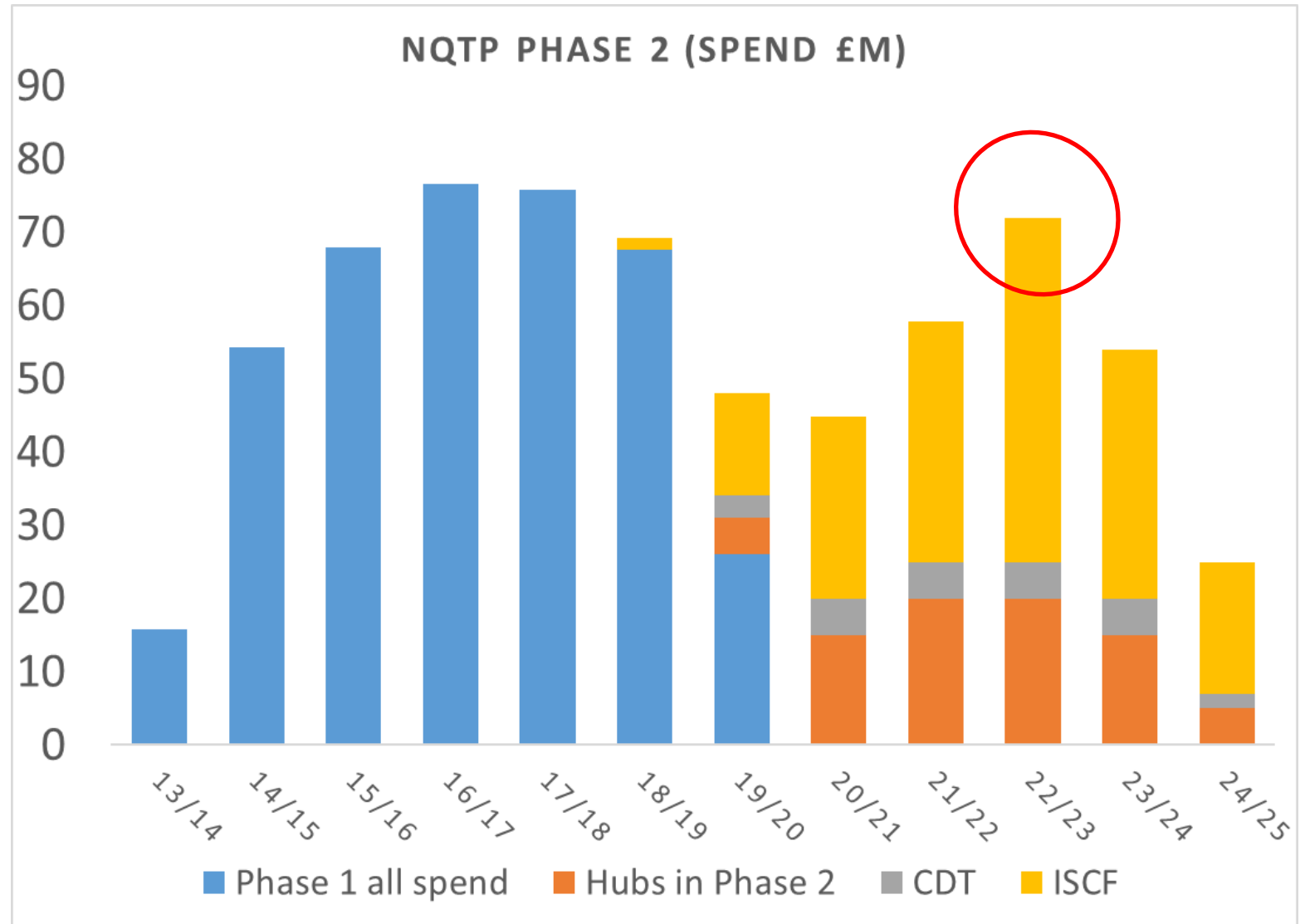
Deployment of full stack Rigetti platform in the UK
Accessible via the cloud
End use applications and new engagements

High-BIAS²

- Lead: ColdQuanta
- 2020-2023
- Advancing the development of a cold atom-based Quantum Positioning System
- Enabling resilient navigation systems without the need for GNSS

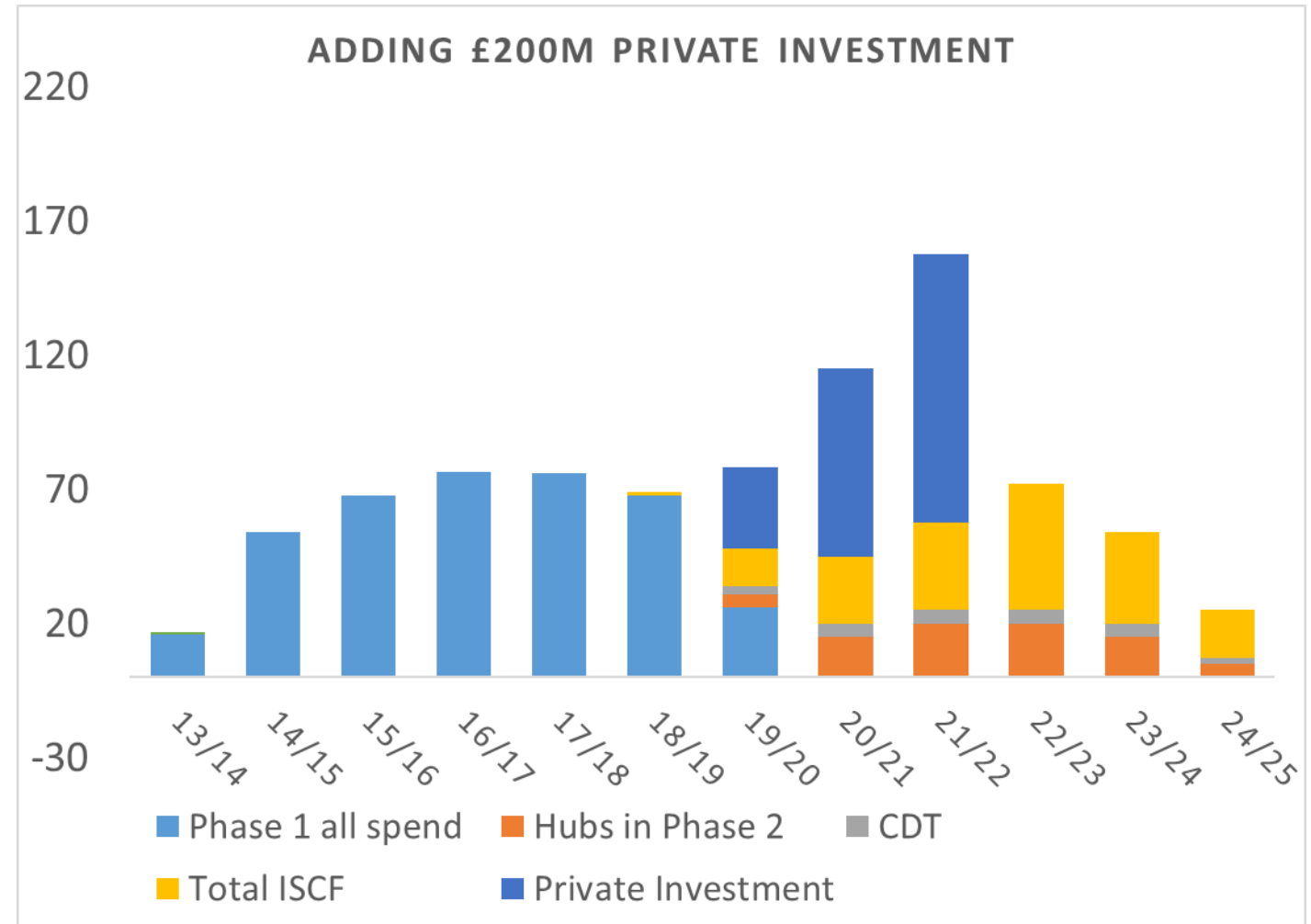


Phase 1 & 2: A few bumps in the road



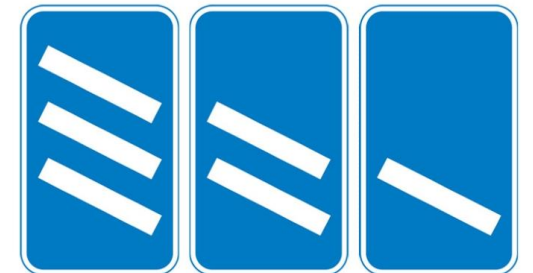
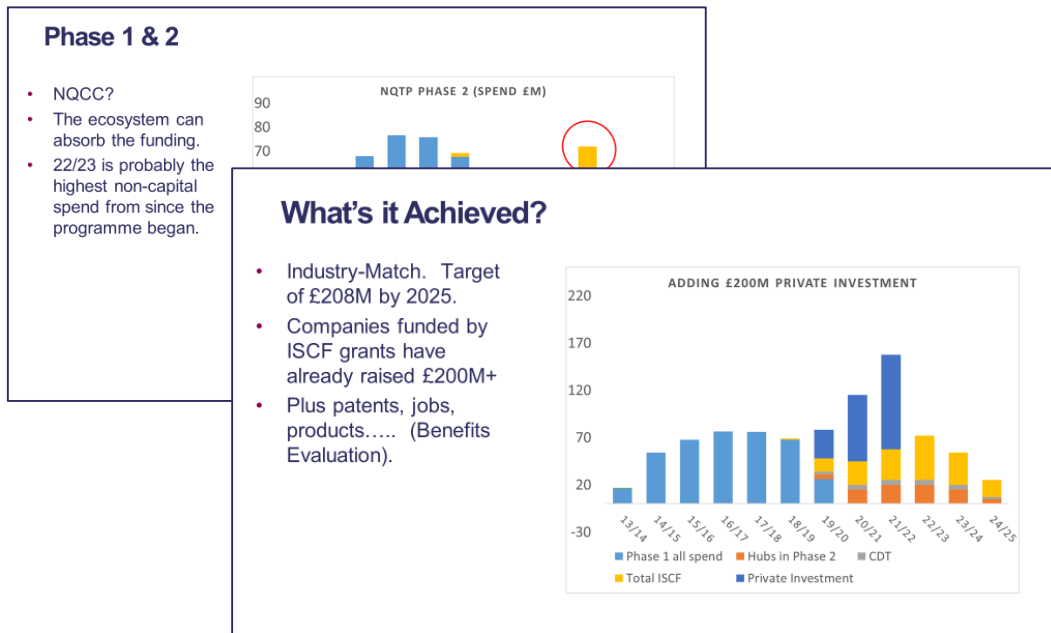
Overcoming the Obstacles

- Grant holding companies have already raised £200M+.
- Growing sector with revenue.
- Thriving ecosystem – no significant gaps.



Counting Down for Phase 3 – What we need to do.

- *We need a phase 3! We need a commitment to another 10 years ideally.*
- *We need to keep funding the science.*
- *We need to address both the areas dominated by private finance and those needing public funding.*
- *We need to continue to develop people: skills and talent.*
- *We need to help markets develop.*
- *We need to consolidate our place in an international community.*



What the key features might be.



- **Keep the science thriving.** Hubs and spokes.
- **Accelerating Growth and Scaling Up.** Not just the ecosystem but specific companies and sectors. (PNT? Computing?)
- **People,** talent and skills.
- **Challenges and Missions:** Intelligent partnership between government and industry.
- **Diversity:** A mixture of *centres, programmes and facilities.*

What's on the Horizon?



