Quantum Computing

A Global Leadership Opportunity for the UK

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What I am going to cover

- The UK Quantum Technology Programme

- The state of the technology and timing

- The global landscape

- The UK vision and opportunity

NQIT Networked Quantum Information Technologies

Introduction to the UK QTP Programme

- In 2014 the UK launched a five year £270m National QT Programme

- Partnership between EPSRC, Innovate UK, Dstl, NCSC, NPL and BEIS

- To turn the UK's strengths in quantum science into a strength in quantum technologies, and make the UK the go to place to research, invest and innovate in QT
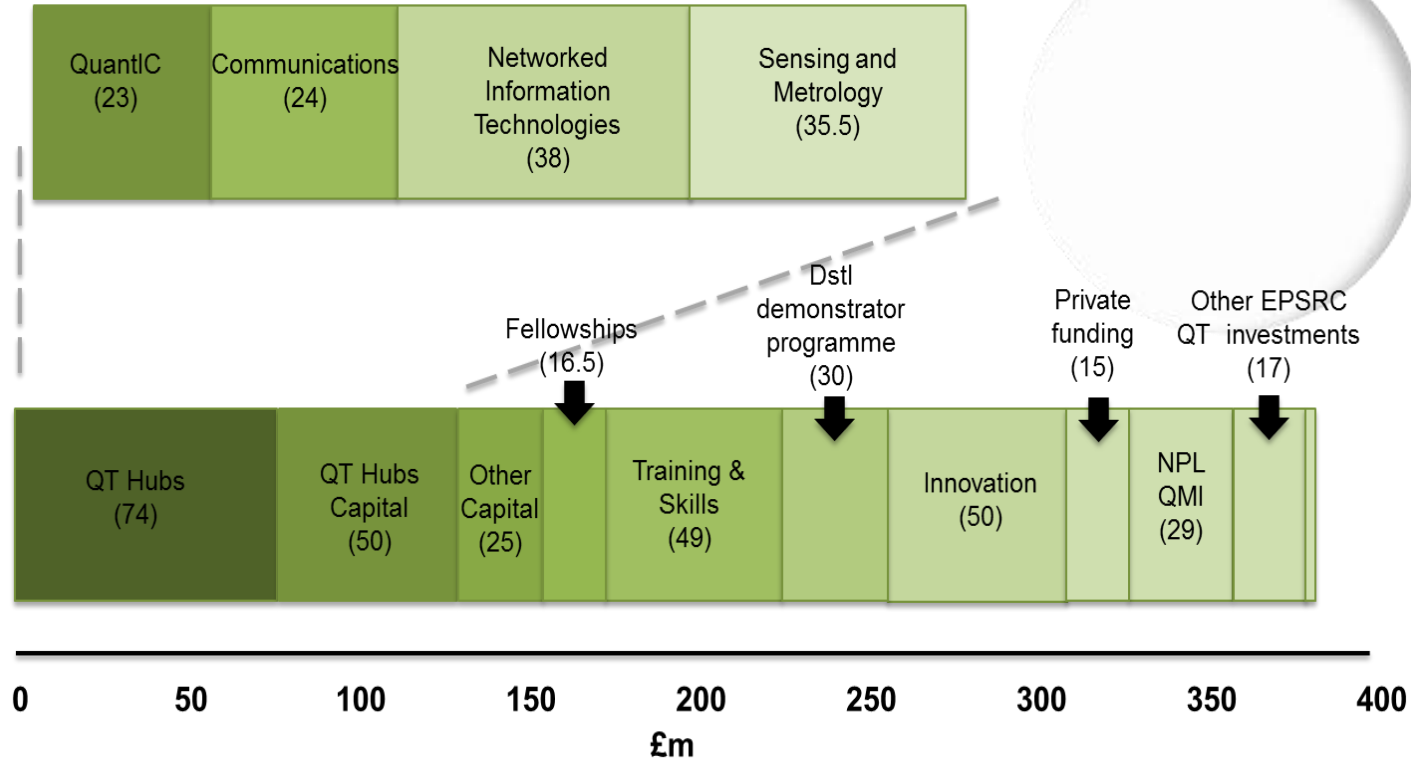
Four main application areas
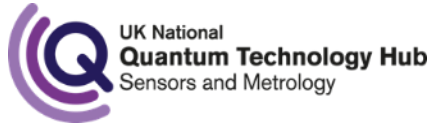
- Quantum Sensors and Metrology

- Quantum Enhanced Imaging

- Networked Quantum Information Technologies

- Quantum Communication Technologies

>20 Universities and >130 Industry Partners

Plus three Quantum Skills Hubs

Investment Phase 1:

Transforming science into technology

- Industry participation from all parts of the value chain:
  - Enabling technologies
  - System building and integration
  - Software and application development
  - Users
- Annual UK QT Showcase: year on year growth in the number of exhibits and attendees
- Technology progress at global leading edge
- Scientific publications, filed patents, start ups and investment, industry-led innovation projects
- Public engagement and substantive RRI results
- Growing cohort of involved scientists and suppliers

NQIT Networked Quantum Information Technologies

Second phase of the UK Programme

- Renewal of the Technology Hubs (£94m)

- Industry led innovation projects (£173m)

- Skills training portfolio (£25m)

- National Quantum Computing Centre (£77m)

- Other announcements (£40m)

Blackett review

The Quantum Age: technological opportunities
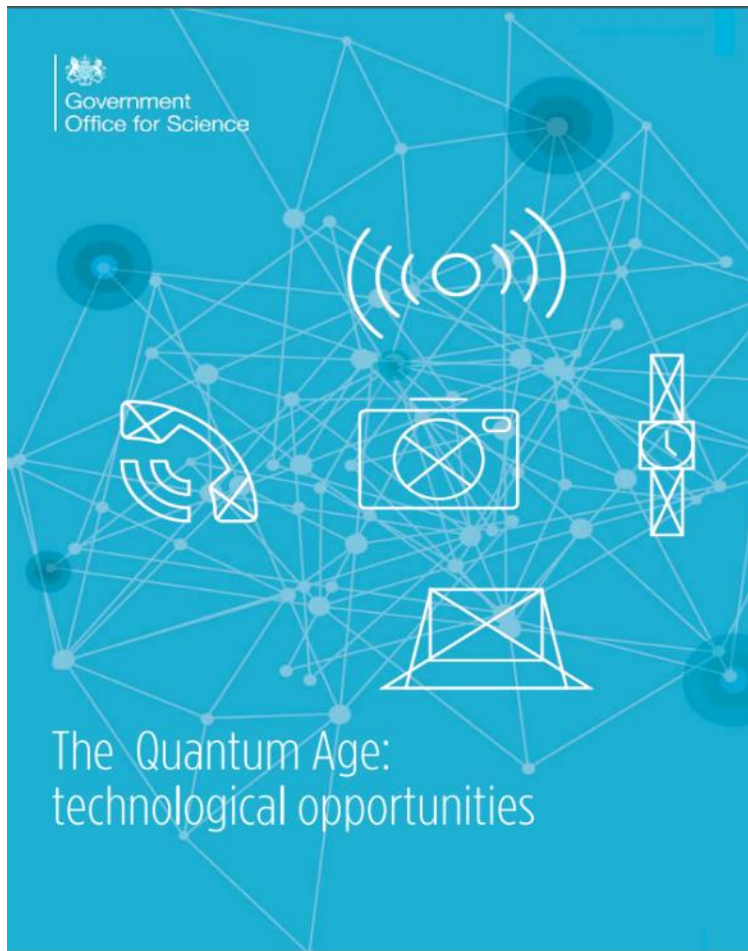
- Launched at the November 2016 National Quantum Technology Showcase.

- Recommended continuation of the a strong UK National Quantum Technologies Programme to maintain our world-leading position in a promising and now globally emerging area of technology.

- Highlights specific applications where quantum technologies are expected to have a profound impact.

The path to Quantum Computing

- A multitude of technology options
  - Superconducting
  - Ion traps
  - Solid state (silicon, diamond)
  - Photonics
  - Topological and more
- Working quantum computing demonstrated
- Development environments emerging
  - QisKit, Cirq, Q#, Forest, ProjectQ etc
- Scalability challenges
  - Qubits, errors and connections (=volume)
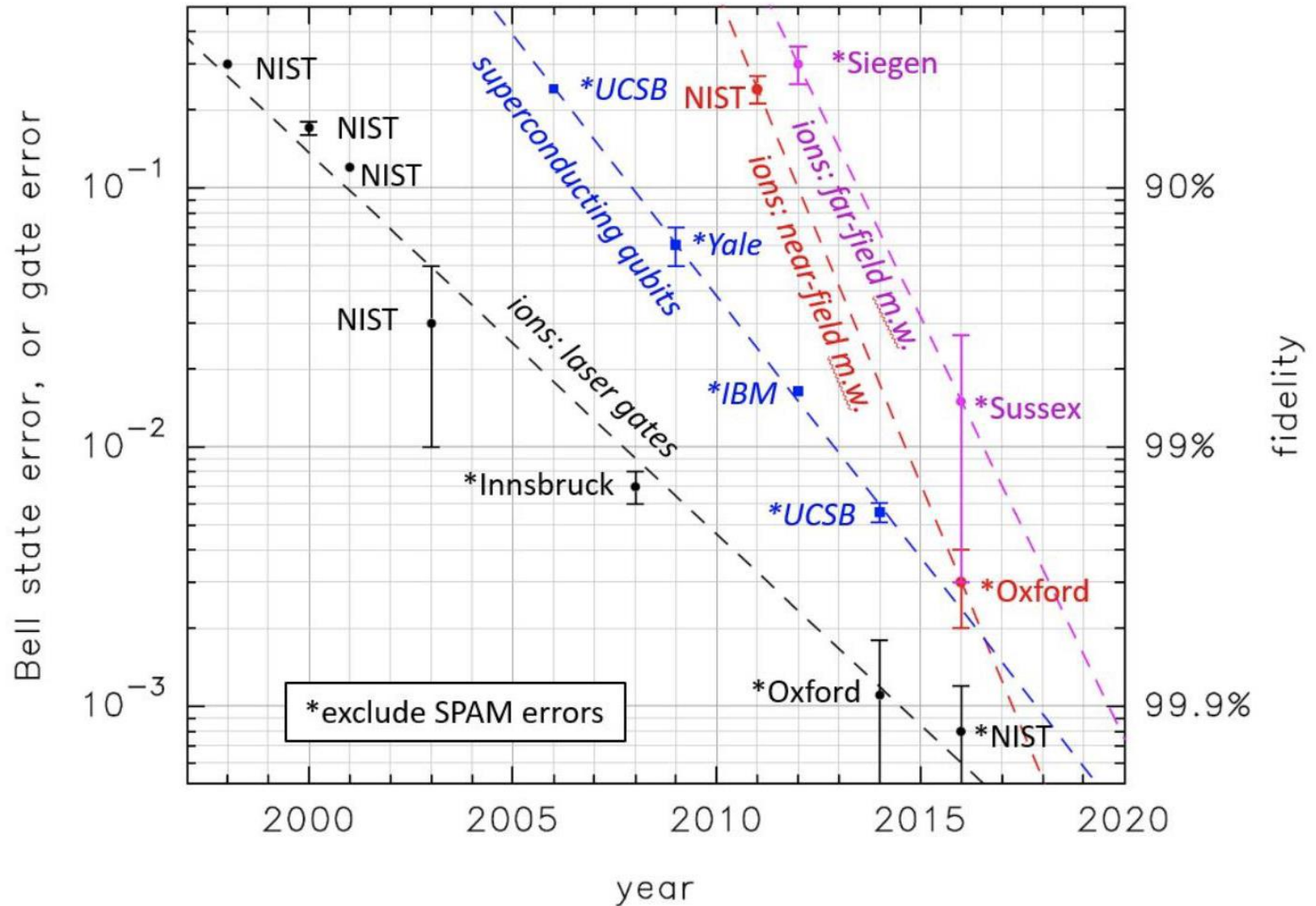- Software systems, then algorithms, then applications

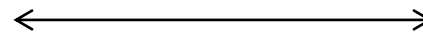# Quantum Volume
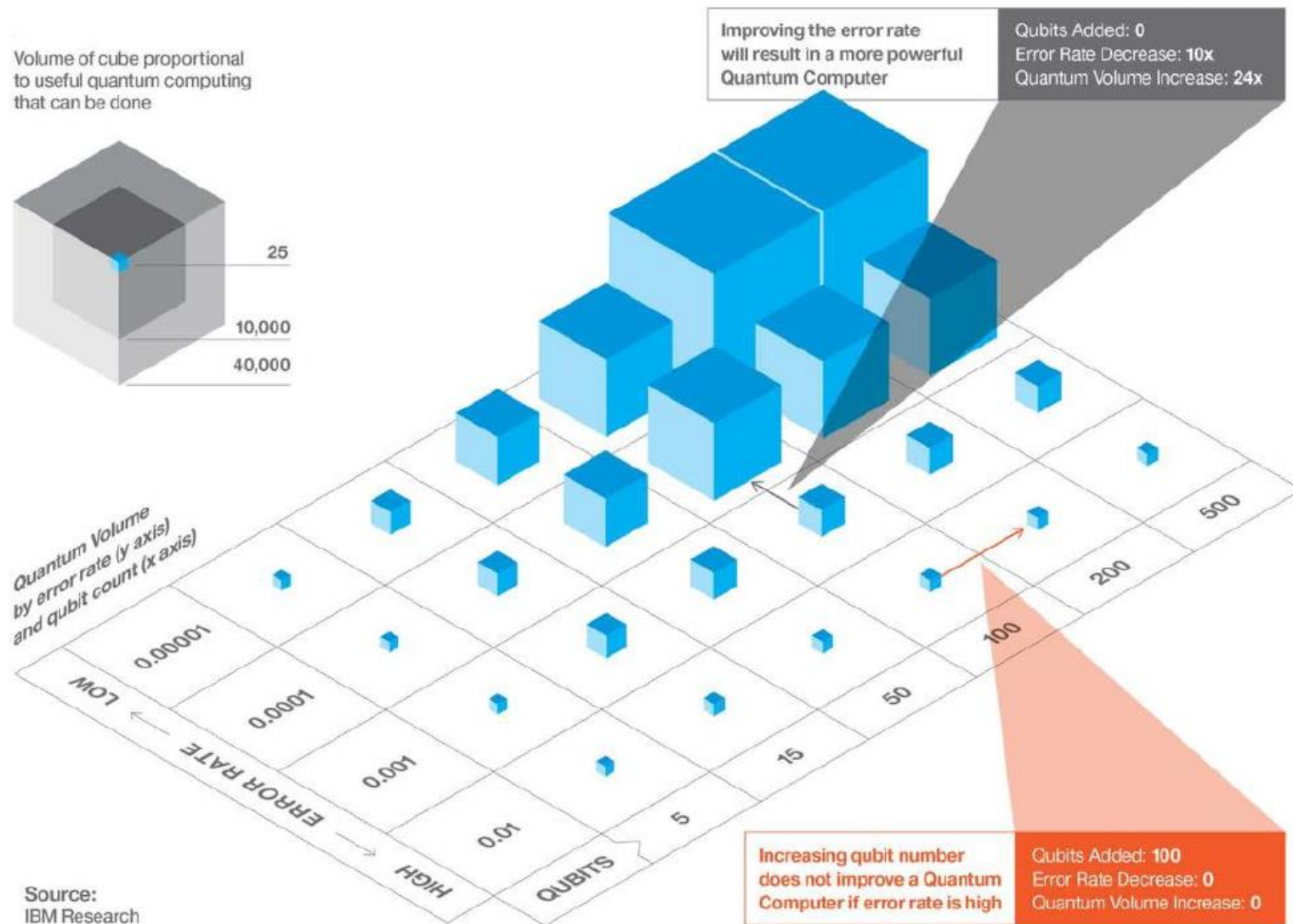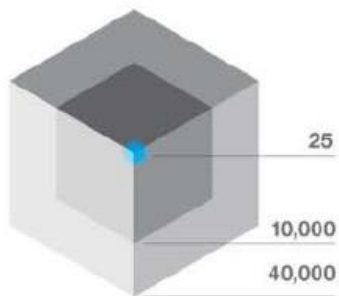
Qubit Errors

Timeline

Today

Classic Quantum Inspired Computing

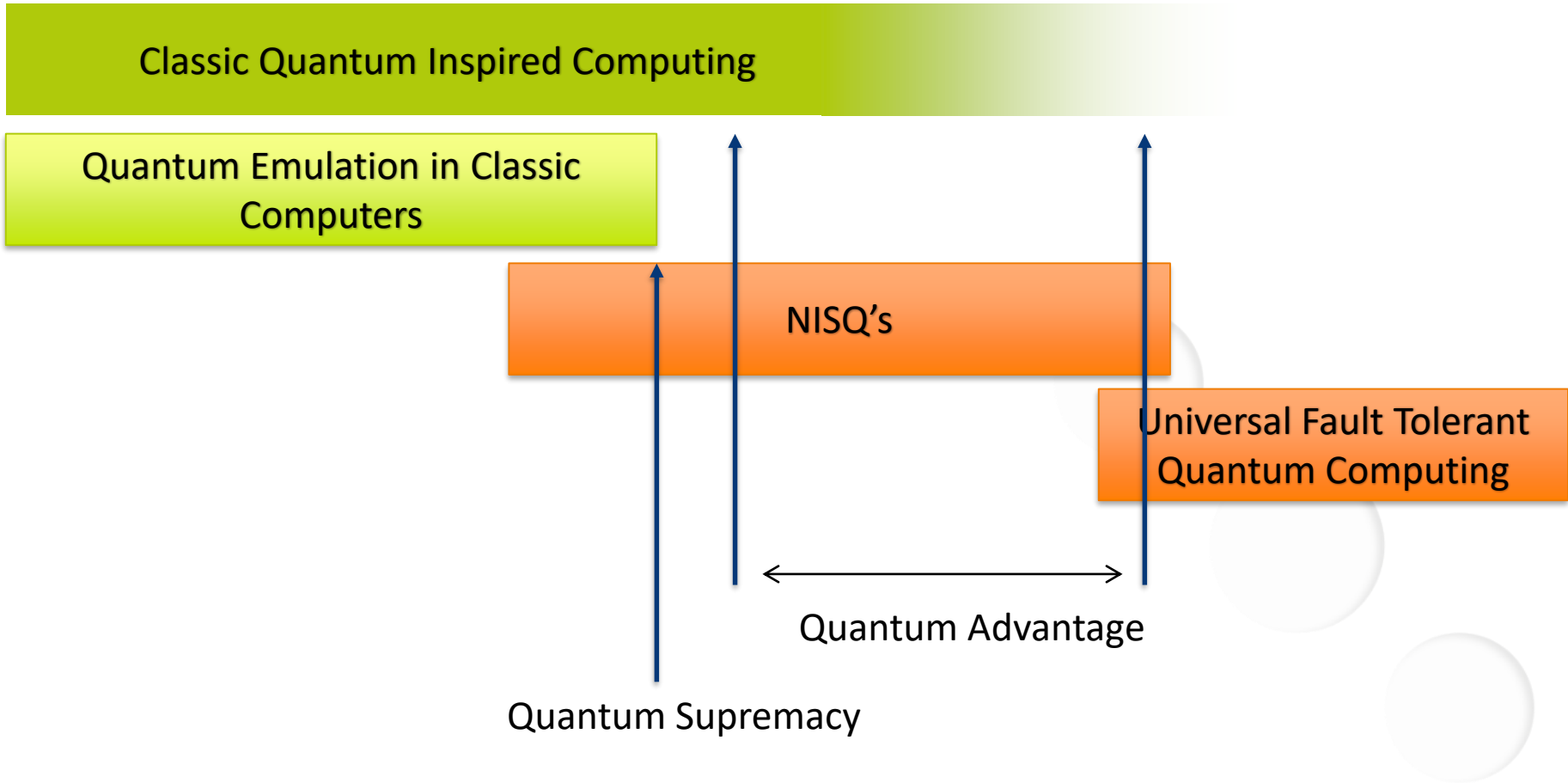Quantum Emulation in Classic Computers

NISQ's

Universal Fault Tolerant Quantum Computing

Quantum Advantage

Quantum Supremacy

Notable Scaling Projects

- IBM, Google, Intel/QuTec, Rigetti: S/C platforms

- OQC, Oxford spinout : S/C QC with novel architecture

- IonQ, Maryland ion-trap QC spinout funded by GV a.o.

- NQIT/Oxford 20:20 ion-trap, UKQTP core, spinning out

- Sussex micro-fabricated ion-trap QC, spinning out

- Honeywell gone public about ion-trap QC development

- Atos 50-100 qubit using ion-traps (with Innsbruck Uni & AQT)

- NSF/Duke "building 1st practical ion-trap QC", DoE funded

- D-Wave annealing QC with 2,000 qubits, 5,000 in 2019

- Advances for longer term in solid state QC's (e.g. silicon, diamond) esp in Europe and Australia and topological QC (Microsoft/Qutec)

The landscape and outlook

- Universities and Research Institutions
- Technology incumbents
  - Google, IBM, Microsoft, Atos, Intel, Alibaba, Tencent, Huawei …
- New technology entrants
  - Honeywell …
- Technology providers and enablers
  - Lasers, fridges, optics, fabricators …
- (Inter-) National programmes
  - EU & members inc UK, Canada, USA, Australia, Singapore, China …
- New ventures and investors
  - D-Wave, IonQ, Rigetti, Quantum Circuits, OQC …
  - CQC, QC Ware, QxBranch, River Lane ….
- Emerging User Community
  - Finance, Engineering, Chemistry, Comms and Logistics …

Example: attendance Q2B Dec 2018

The UK Opportunity

- World-class research base
- First comprehensive national Q technology programme
- Technologies capable to deliver a scalable QC
- A comprehensive programme for enabling technologies
- Creating robust software stack and algorithms as platforms for future application development
- Building and attracting skills
- Engaging with industry, service organisations, science, public and investors

An Opportunity to build a new UK quantum industry that leads the world and gives the UK industry, science and society an unique advantage

An emerging industry

NQIT associated new ventures
- Oxford HighQ (Oxford)
- Oxford Ionics (Oxford)
- Oxford Quantum Circuits (Oxford)
- Q&I (Bristol, Edinburgh, Oxford, UCL,
- QDia (Warwick)
- Quantum Motion Technologies (Oxford, UCL)
- Quantum Photonics (Bath, Imperial)
- Universal Quantum (Sussex)
- VeriQloud (Bath, Edinburgh, Paris)

Other recent UK quantum ventures
- Cambridge Quantum Computing
- River Lane (Cambridge)
- PhaseCraft (UCL & Bristol)
- KETS Quantum Security (Bristol)
- PQ Solutions (Plymouth)
- Quantum Nu (Cambridge)
- Rahko Ltd (UCL)
- PQShield (Oxford)
- VeriVin (Oxford startup)

Collaborations
- Atos – STFC Hartree QLM
- Google/Bristol/UCL Prosperity Partnership
- Oxford IBM Q Hub

Inward investment
- QxBranch (USA, London branch)
- ColdQuanta (USA, UK office)
- D-wave (Canada, Commercial office)
- In-Q-Tel (USA, planning London office)

QT Research Hub

- Quantum computing and simulation: new Hub will include all UK world-leading research on challenges to scalability, architecture and operating system for quantum computing and simulation

- Ensuring the UK maintains a leadership position in its areas of strength while remaining flexible to other approaches to quantum computing

- Continue an intensive User Engagement Programme including user awareness and skills development, collaborative research, technology commercialisation including startups and spinouts and public engagement and RRI activity

- Work closely with the National Quantum Computer Centre and its users and suppliers

National Quantum Computing Centre

To accelerate the UK's efforts in quantum computing and secure the benefits of this technology for the UK
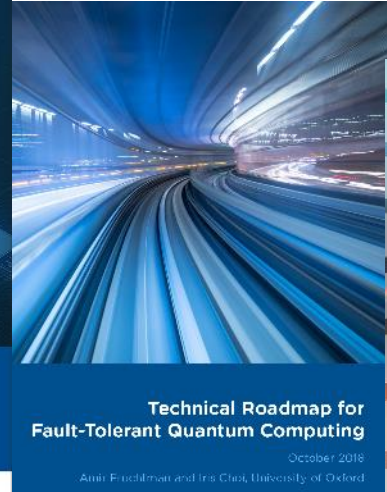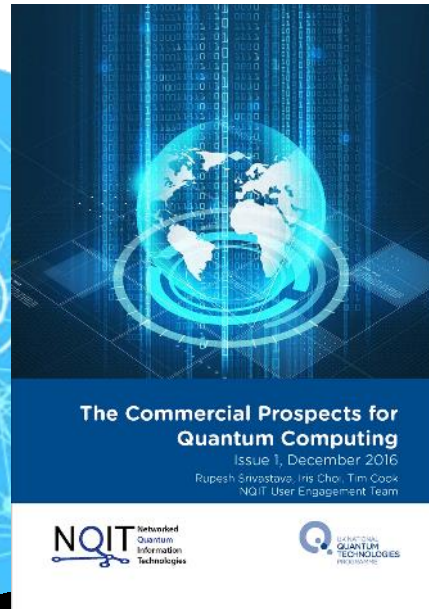
- Build demonstrators at scale
- Developing software and algorithms
- Exploring applications as the capability grows

- Work towards a fully scalable, FTQ while also working on emulators, simulators and NISQs

- Part of a wider UK quantum computing landscape

- A primary site for the Centre with activities at secondary locations and by partners delivering it, and through collaboration

NQIT Networked Quantum Information Technologies

How to Participate

- Technology Hubs
  - information, collaborative research, opportunities for students and researchers
- NQCC
  - Awareness and training, platform access for scientists and industry for pre-competitive and proprietary development
- InnovateUK calls
  - Industry led innovation projects through consortia, for SME's and feasibility studies
- IBM Q Oxford Hub
  - Access to early development platform and support from IBM and Oxford University
- Quantum Readiness Programme CQC & NQIT
  - Series of awareness sessions aimed UK-based organisations
- Hackathons
  - Oxford 15 March, Edinburgh 2-5 July
- IBM Experience, Rigetti online, D-Wave online
- Science festivals
  - Quantum City initiative

More Information

https://nqit.ox.ac.uk

Thank you