McKinsey & Company

# The Quantum Technology Monitor

## FACTS & FIGURES

DECEMBER 2020

# What is the Quantum Computing Monitor?

- Dynamic overview of industries' **maturity toward quantum computing,** based on the current application of the technology
- Continuously evolving overview of the **global quantum computing player & investment space,** updated 6-monthly

**… and what it is not:**

- **Definitive & exhaustive list** of the start-up and funding activities in the quantum computing realm as it evolves too rapidly

# Key Facts

60% of start-ups and incumbent companies in the G7 are located in North America

G7 members account for more than 70% of quantum computing startups worldwide[1]

Investments in the past 5 years show a compound annual growth rate of 80% with 0.5 billion USD in 2020 alone representing about one third of all investments so far

About 90% of investment is focused on hardware manufacturers

~60% of quantum computing players are active in the systems and algorithm layers

Quantum computing hardware manufacturers are 35-40 globally

1. Excluding China, due to a lack of data

NOT EXHAUSTIVE

# Quantum technologies are accelerating

**Not Exhaustive**

Quantum computing | Quantum communications | Quantum sensing | Quantum overall

## 2000

**1999**

EU invests €50-75 million in quantum technologies via Future and Emerging Technologies (FET) program over next 7 years (EU Flagship program)

**1999**

First commercial special-purpose QC company is founded

**2001**

First announcement of commercial R&D project on QComms

**2003**

DARPA launches the first quantum network; it becomes fully operational in October 2003

**2007**

First commercial offer of quantum key distribution services is launched

**2007**

The local government of Geneva protects voting systems with quantum key distribution for a federal election

**2011**

First sale of a special-purpose quantum computer is announced at the price of $10m

**2012**

First QC software company is founded

**2014**

Total yearly investments in QTs exceed $100 m for the first time; more than 10 QT companies are founded

## 2015

**2016**

Large technology company offers open and premium access to their quantum computer

**2016**

First testing of quantum key distribution on commercial fiber lines

**2016**

Canadian government commits $ 76 millions to the University of Waterloo for quantum hardware and software

**2017**

First industry announcement for QC partnership, in the automotive industry

Several dozens of startup are founded

**2018**

First commercial Quantum 2.0 sensor, a gravity sensor, is launched

**2018**

First industry announcement for QC partnership in the chemicals industry.

Large technology companies start to incubate and consolidate the start-up ecosystems

**2018**

EU commission announces a €1 billion project for support of quantum researchers over the next ten years (EU Flagship program)

## Today

**2019**

Launch of first online QC platform via the cloud by large technology company

**2019**

Launch of first quantum cloud service offering access to hardware of multiple providers through one platform

**2019**

US company makes the first claims to “quantum supremacy”[1]

**2020**

World’s most powerful quantum computer (volume 128) is announced

1. Quantum supremacy: an event defined by the resolution of a quantum computation that cannot be done by the most powerful classical computers in a practical amount of time

Source: McKinsey analysis, expert interviews, press search

# Public funding for quantum computing

**NOT EXHAUSTIVE**

**2.5** bn USD p.a.

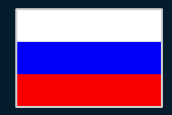
**2.7** bn USD

**2.2** bn USD

**1.2** bn USD

**1.2** bn USD

**0.9** bn USD



**0.8** bn USD

**0.8** bn USD

**0.5** bn USD

**0.1** bn USD

Less than **0.1** bn USD

Source: CSIRO, McKinsey analysis

# Several industries are already working in “stealth mode” on competitive applications of quantum computing

Adoption of quantum computing technology, by industry vertical

## Bystanders

- No explorative activities in the realm of quantum computing have publicly been announced by the industry’s players so far

## Beginners

- Industry players formed first partnerships and/or consortia to explore first quantum computing use cases (pre-competitive)

## Amateurs

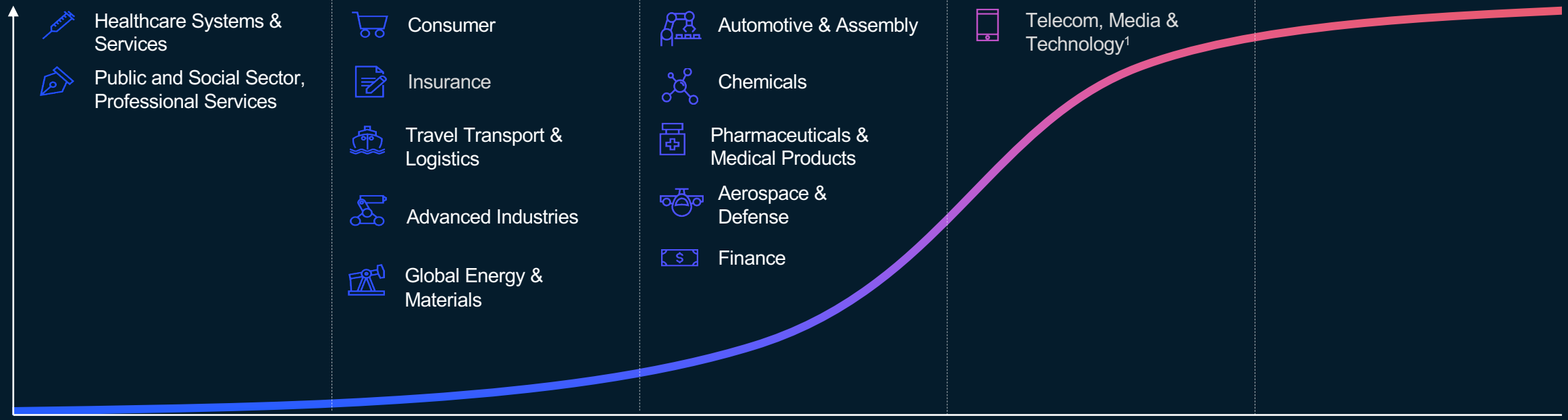
- Several pre-competitive activities have moved to a competitive stage and industry players start to hire quantum scientists

## Professionals

- Industry players start to realize business impact via proprietary quantum computing applications and adhere to a strategy

## Legends

- Innovation related to the applications of quantum computing in an industry plateaued but use cases continue to create value




1. Technology companies are quantum computing hardware manufacturers and software developers

Source: McKinsey analysis

# Experts expect the impact of quantum computing in the mid-term to be greatest in AI, GEM, Finance and TTL

**Horizons:** Primary value pools (until ~2025) | Secondary value pools (beyond ~2025)

**Economic value:** + Low ++ Medium +++ High

**Value share:** Low Medium High

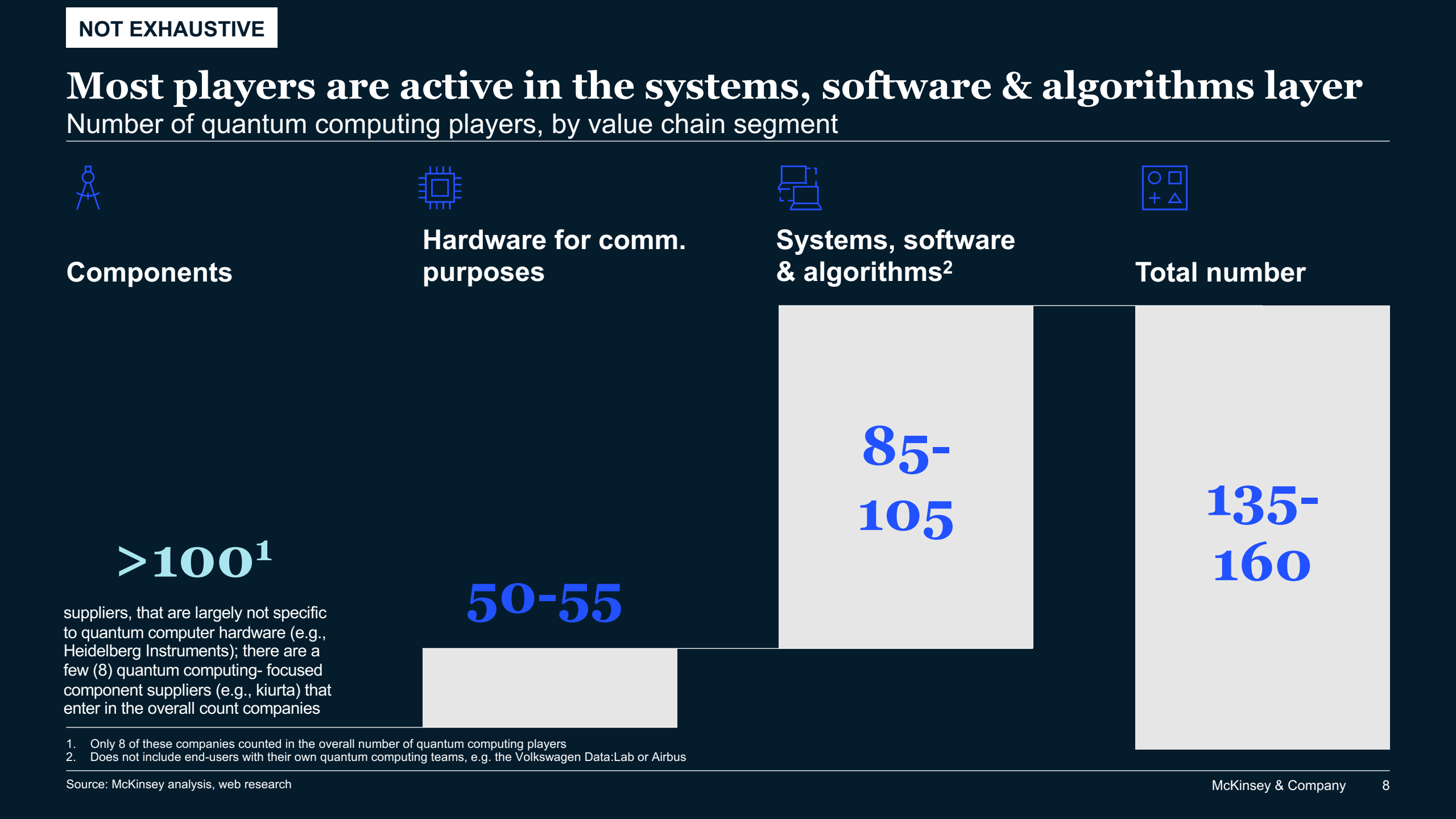
| | Economic value | | Economic impact share | | | |
|---|---|---|---|---|---|---|
| | ~2025 | ~2035 | Quantum simulation | Optimization | Quantum AI/ML | Prime factorization |
| Advanced Industries | + | ++ | Low | Medium | Medium | Low |
| Consumer | + | + | Low | Medium | Medium | Low |
| Global Energy & Materials | ++ | +++ | High | Medium | Medium | Low |
| Telecom, Media & Technology | + | ++ | Low | Medium | Medium | Medium |
| Finance | ++ | ++ | Low | Medium | Medium | Medium |
| Insurance | + | ++ | Low | Medium | Medium | Medium |
| Healthcare Systems & Services | + | + | Medium | Medium | Medium | Low |
| Pharmaceuticals & Medical Products | ++ | +++ | High | Medium | Medium | Low |
| Travel Transport & Logistics | + | ++ | Low | Medium | Medium | Low |
| Public and Social Sector, Professional Services | + | ++ | Low | Medium | Medium | Low |

Source: McKinsey analysis

NOT EXHAUSTIVE

# Most players are active in the systems, software & algorithms layer

Number of quantum computing players, by value chain segment




1. Only 8 of these companies counted in the overall number of quantum computing players
2. Does not include end-users with their own quantum computing teams, e.g. the Volkswagen Data:Lab or Airbus

Source: McKinsey analysis, web research

NOT EXHAUSTIVE

# The US and Canada are most active around quantum computing

Number of quantum computing players (excl. China), by country and origin

Geographic details on next slide

| **Number of QC players,** by country | | **Start-ups** | **Incumbent companies** | **Public- /gov.-organizations** | **Academic groups** |
|---|---|---|---|---|---|
| **Top 7** |  | 36 | 13 | 14 | 38 |
| |  | 20 | 0 | 1 | 9 |
| |  | 13 | 0 | 1 | 7 |
| |  | 7 | 0 | 2 | 4 |
| |  | 7 | 1 | 0 | 5 |
| |  | 7 | 1 | 3 | 1 |
| |  | 6 | 0 | 2 | 1 |
| **… and elsewhere[1]** | | 31 | 3[2] | 19 | 24 |
| **Σ** | | **127** | **18** | **43** | **89** |

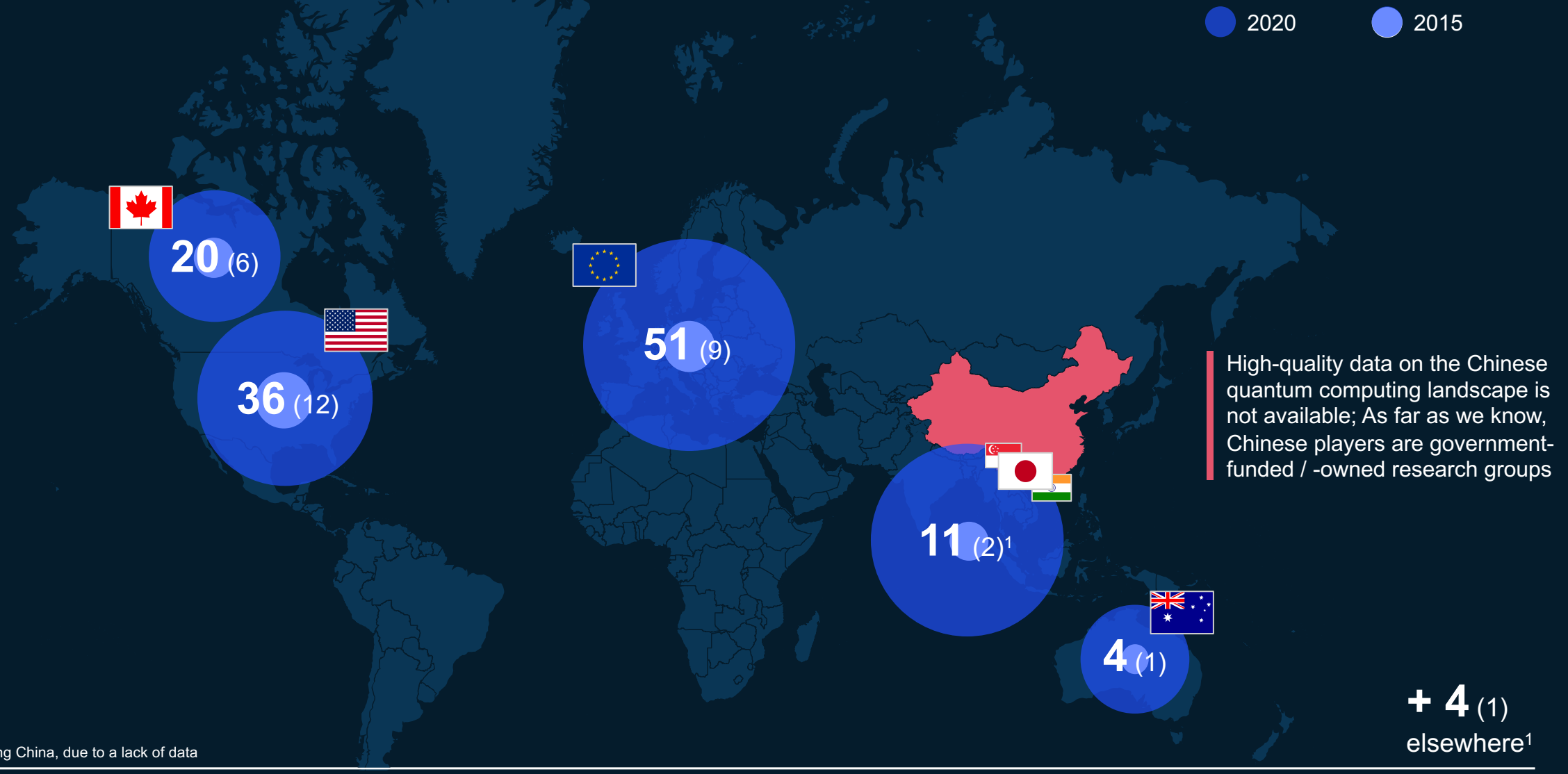
1. Excluding China, due to a lack of data
2. Includes Chninese companies Baidu and Alibaba

Source: McKinsey analysis, web research

NOT EXHAUSTIVE

# We have seen a stark rise in quantum computing start-ups globally

Number of quantum computing start-ups (excl. China), by region (today, and 2015 in brackets)



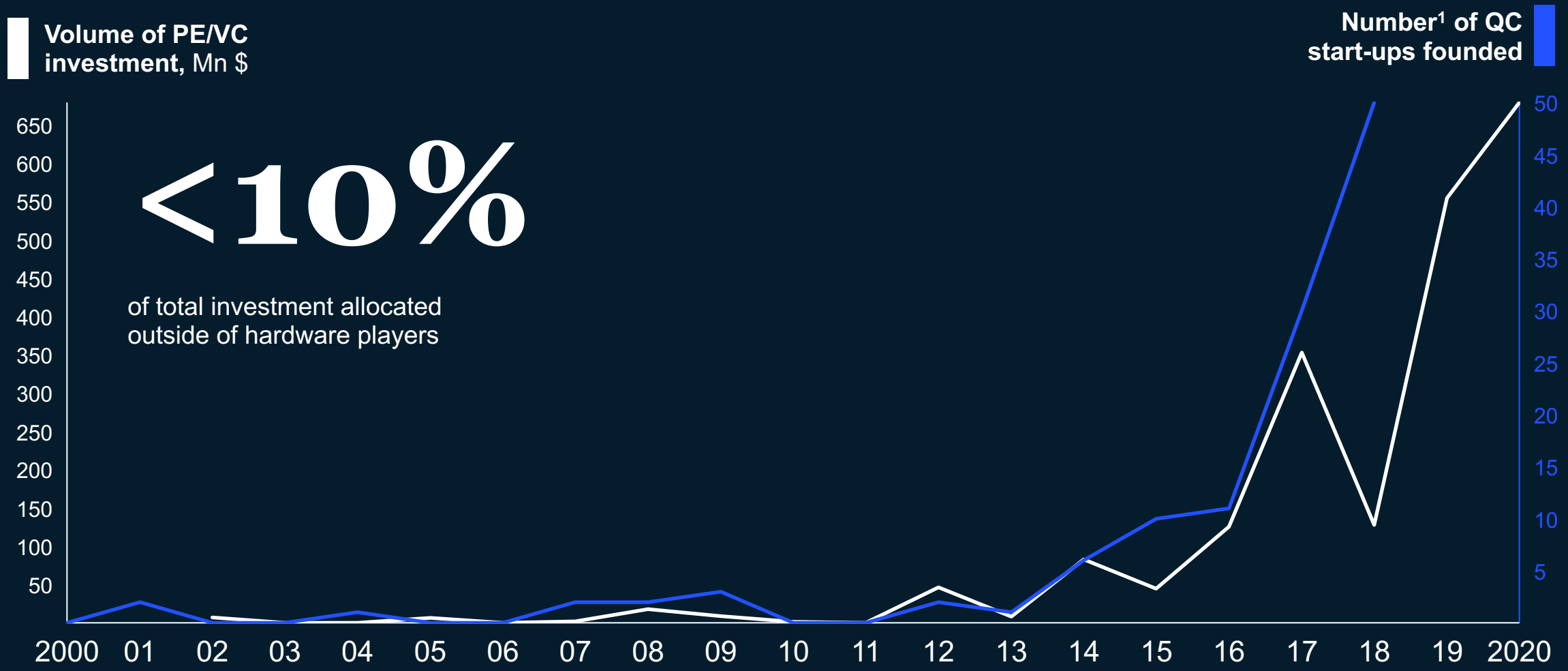

1. Excluding China, due to a lack of data

Source: McKinsey analysis, Pitchbook, Crunchbase

NOT EXHAUSTIVE

# Founding & investment activity has grown rapidly in the last 5 years

Number new foundings / investment volume, by year




**<10%**

of total investment allocated outside of hardware players

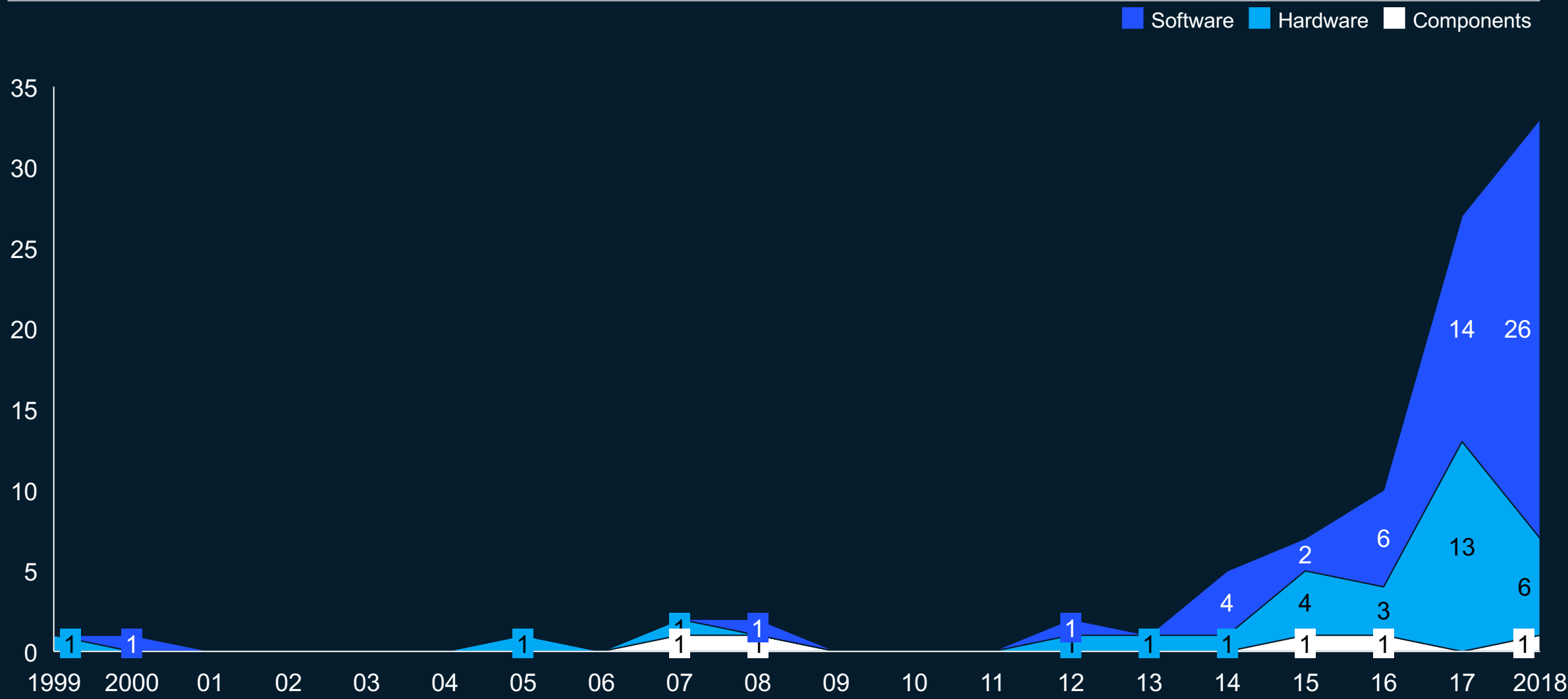
1. Number only quoted until 2018, since start-ups with a later founding date may still be in "stealth" mode, i.e. they have not disclosed their activity publicly

Source: McKinsey analysis, Pitchbook, Crunchbase

NOT EXHAUSTIVE

# Most newly founded start-ups are software & algorithm developers

Founding activity[1] in quantum computing (excl. China), by new founding volume per year




1. Number only quoted until 2018, since start-ups with a later founding date may still be in "stealth" mode, i.e. they have not discolsed their activity publicly

Source: McKinsey analysis, Pitchbook, Crunchbase

# Development of QC in China is driven by start-ups and researchers linked to the government

## ~1

Billion USD Funding for a governmental laboratory

### National Quantum Information Sciences Laboratory

First provincial and ministerial level key laboratory in the field of quantum information in China

Focus on theoretical and experimental research on quantum communication and quantum computing

The project is invested in total 7 billion RMB, and is completed and delivered by September 30, 2020

**In December 2020, researchers from the Hefei National Laboratory claimed quantum supremacy with a photonic prototype**

## 3

Startups are active in commercial quantum computing

### Origin Quantum Computing

Founded in 2017 by a research team of the quantum information lab at the Chinese Academy of Sciences

Offers QCPU, quantum controlling hardware, quantum software, quantum cloud. In Sep 2020, Origin began to operate China's first superconducting quantum computer outside the lab

### Qasky

Founded in 2016 to commercialize quantum cryptography research at the Academy of Sciences

Plan to offer products and services for integrated solutions for quantum information security systems

### QuantumCTek

First Chinese provider of multi-protocol network security products and services based on quantum

## 517

Patents related to quantum computing filed in China in 2018 (twice as many as US)

### Related activities

Large Chinese companies are interested in quantum products:

One software provider is engaging in Quantum AI and the design of computing architecture

A tech company is hosting a quantum computing cloud with an 11-qubit computing-device backend

Source: Press clippings, web research

# Where is quantum headed?

- The race for technological leadership will continue between photonic, trapped-ion, and superconducting qubit devices
  - IBM announced a ~103 qubit superconducting chip by 2023, more than an order of magnitude larger than the current Hummingbird chip
  - Honeywell aims to gradually scale its ion trap technology and manufacture large-scale quantum computers for commercial applications by 2030
  - PsiQuantum announced that it will manufacture a commercially-viable quantum computer with ~$10^6$ qubits by 2025
- More players across industries will move from pre-competitive explorations of quantum computing into competitive research (partly in “stealth-mode”)
- Several large investment rounds have already been announced for 2021 (e.g. Xanadu, ~100 mn USD), suggesting that the investment activity around quantum computing will continue to rise despite the COVID-19 pandemic
- Chinese researchers have made a claim to quantum supremacy (for a boson-sampling problem) in December 2020, and local research is expected to yield more breakthrough results backed by the ~10 bn USD government fund for quantum computing

# The team behind the Monitor

**Niko Mohr**
Partner
Dusseldorf

**Anika Pflanzer**
Partner
Munich

**Henning Soller**
Partner
Frankfurt

**Mathis Friesdorf**
Associate Partner
Berlin

**Matteo Biondi**
Specialist
Zurich

**Philipp Hühne**
Digital Communication Specialist
Dusseldorf

**Lorenzo Pautasso**
Fellow Associate
Munich

# Appendix

# Classical computing

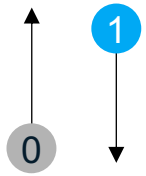
**Alan Turing**

"Father" of
classical computing

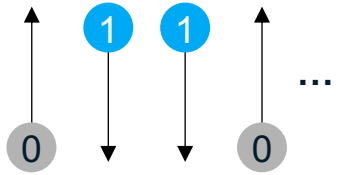
## 1 classical bit


Bit can store
zero or a one

## 2 classical bits

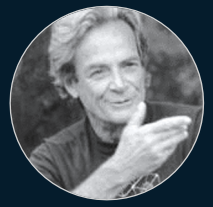



## N classical bits




Source: McKinsey analysis, expert interviews, press search

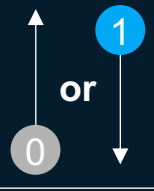
# Quantum computing



**Richard Feynman**

"Father" of
quantum computing

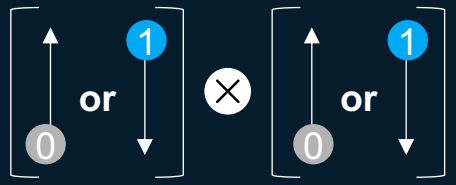
## One quantum bit




Superposition state of two quantum states 0 and 1

**2** (complex) coefficients are required to describe the superposition

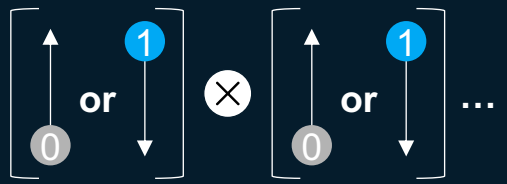
## 2 quantum bits




Superposition state of 4 quantum states 00, 01, 10, 11

**4** (complex) coefficients are required to describe the superposition

## N quantum bits




Superposition state of N quantum states 0000…, 1000…, 01000…, etc.

**2N** (complex) coefficients are required to describe the superposition

Exponential complexity to leverage as computational power

Simplicity of read-out

# Methodology

**Quantum computing temperature and industry positioning (pp 6-7)**

- The quantum computing temperature (pp 6) is based on a survey across +300 industry leaders globally and their opinion on the impact of quantum computing on their respective industry
- The impact estimation and impact share across quantum capabilities (pp 7) is based on a survey across +100 McKinsey experts and industry leaders

**Quantum computing player landscape and investment (pp 3, 4, 8-14)**

- To obtain the Quantum Computing player landscape, we considered the following entities
  - Startups: founded in the last 25 years with estimated revenues below 200 million USD
  - Incumbent companies: companies with revenues above 200 million USD
- *Hardware manufacturers* are considered such, if they have already demonstrated the creation of a quantum computer or have announced efforts in this direction
- *Systems, software and algorithms* include all companies and startups which develop dedicated software or applications for quantum computing. Hardware manufacturers which also develop dedicated software solutions are also included in this group
- Investments in startups has been extracted from Pitchbook and Crunchbase and amended by McKinsey analyses
- We could not obtain high-quality data on the quantum computing landscape in China due to most quantum efforts being kept secret.