Trajectory of Quantum Technologies in China

U-Corp @ World Economic Forum

Edessa Sahin, Hanyang Zhou, Jinchen Zhao, Yihuan Wang

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Outline

- What are QTechnologies?
- Why does China want to develop QTechnologies?
- What is the current state of QTechnologies in China?
- Challenges of QTechnologies in China

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What are Quantum Technologies?

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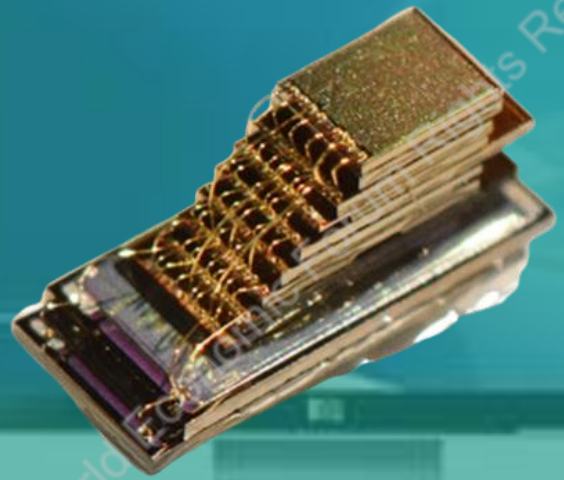
IBM
summit


summit
IBM

Michigan Micro Mote (M^3)



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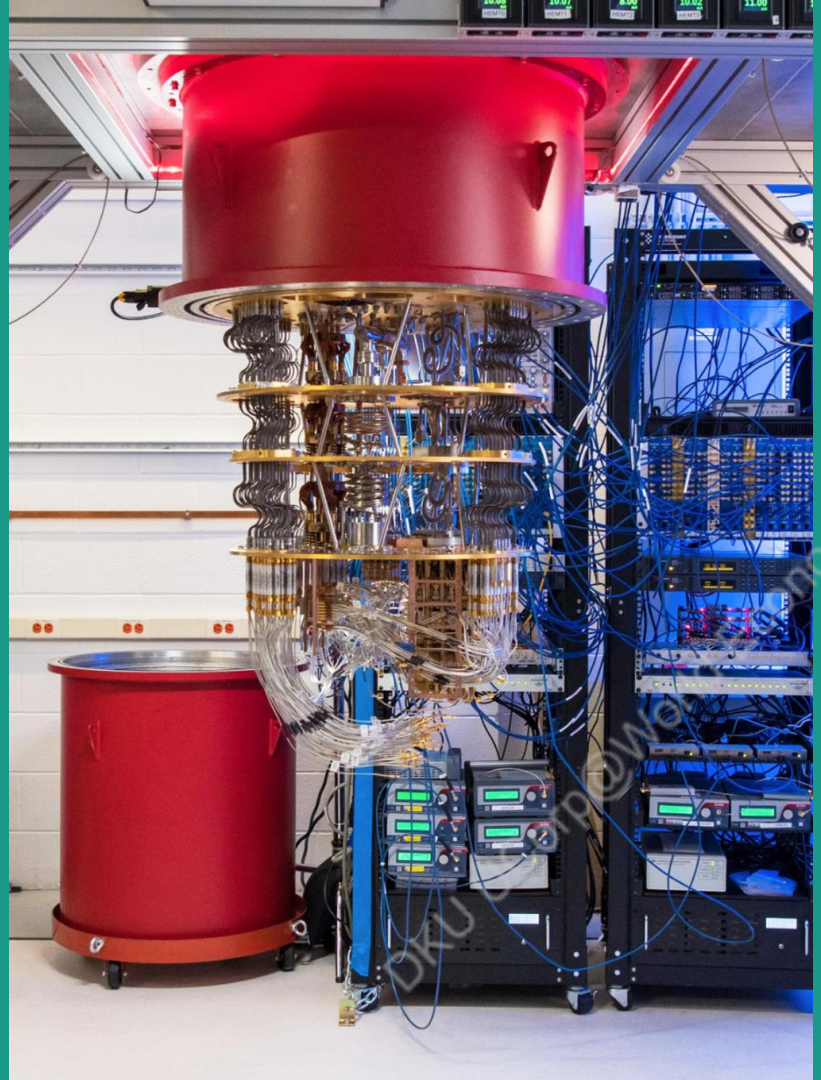

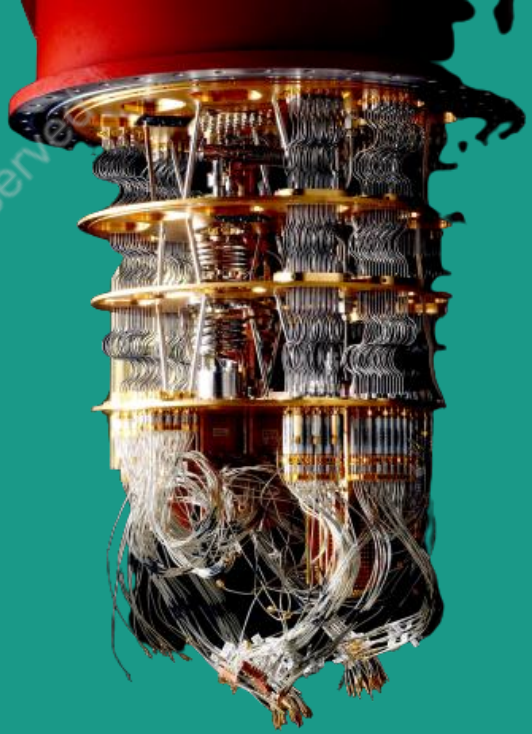

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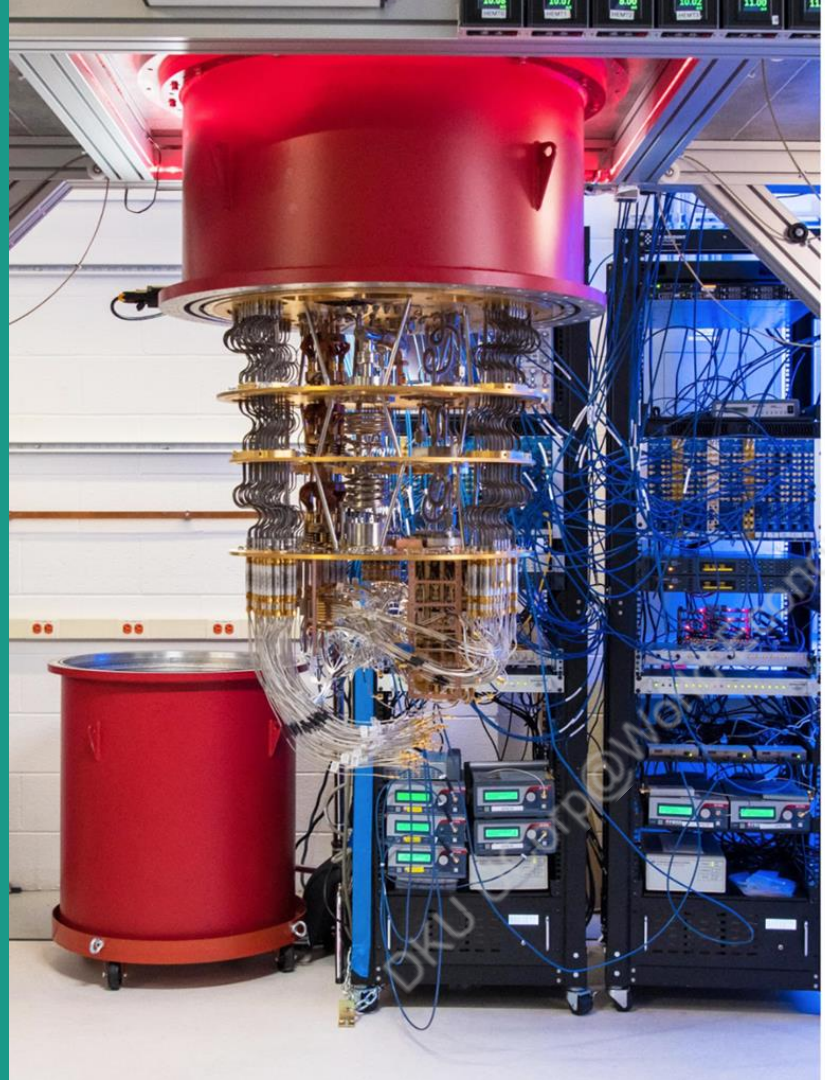

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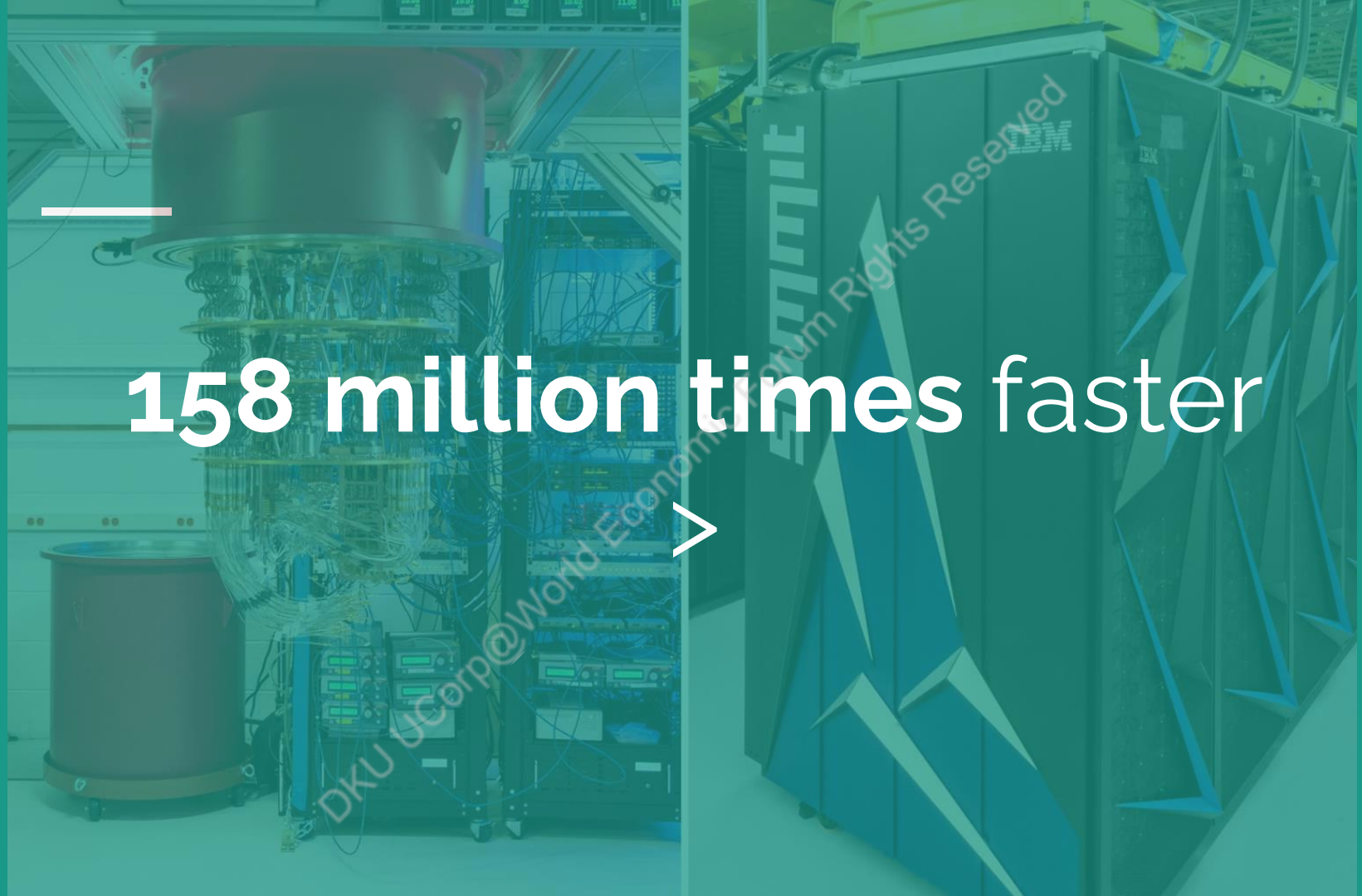

158 million times faster

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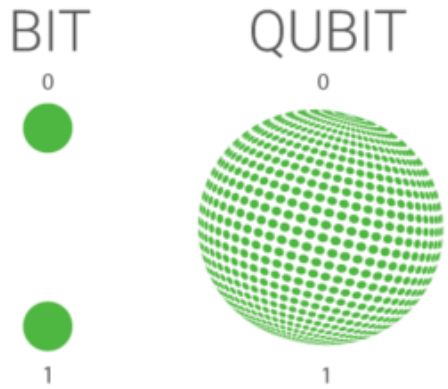
Quantum Computers



- Information is stored in Quantum bits (vs classic bits)
- Infinite, continuous number of possible states
- Data processing is carried out by Quantum logic at parallel instances
- Circuit behavior is defined by quantum mechanics → higher efficiency, speed, and security
- Go beyond the limits of supercomputers in some specific tasks
- Will NOT replace classic computers altogether

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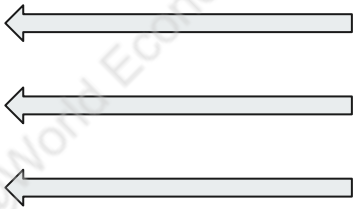
Quantum Computing and Quantum Technologies

Technologies:

- Quantum Communication
- Quantum Computing
- Quantum Sensing



Sectors:

- Cyber and Information Security
- Finance
- Pharmaceuticals
- Material Science and Research

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Why does China want to develop Quantum Technologies?

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QTech's Stratigic Values

- National security: Quantum algorithms may break the current public security system
- On the other hand, quantum communication is unbreakable by nature!
- China has been a follower in technological advances, now it can be a leader

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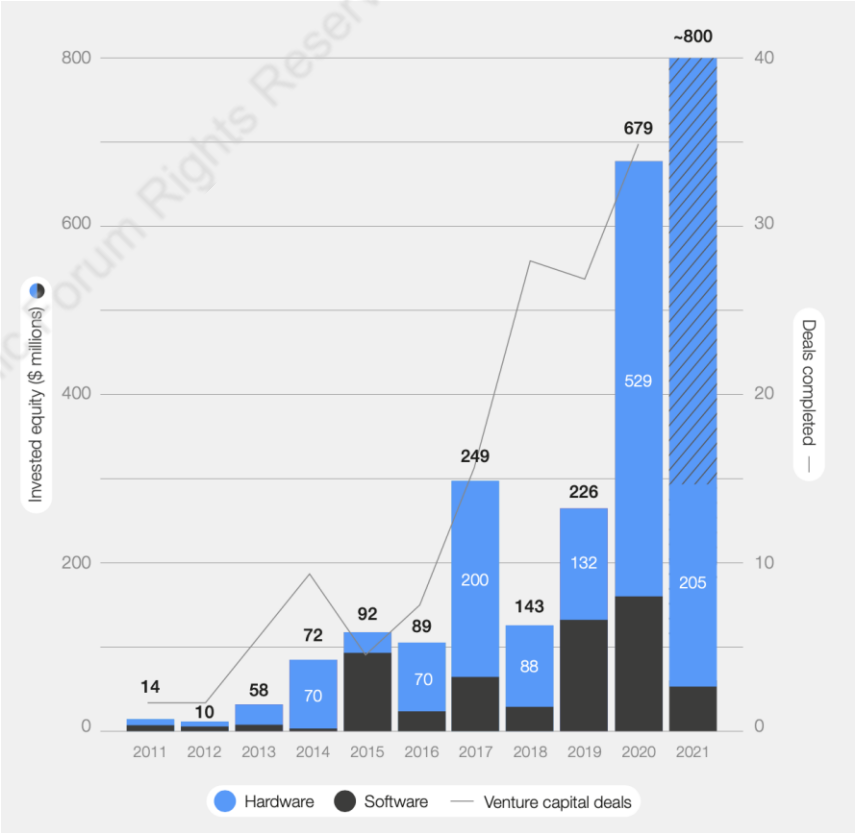
The Global Competition

- American companies like Google, IBM, Microsoft started QTech investment very early
- Chinese companies need to stay competitive in the global market
- Increasing technological sanctions on China



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What is the current state of QTechnologies in China?

- Compare China with West
- China’s public policy
- China’s private sector

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Comparison of Chinese and Western QTechnology Investment

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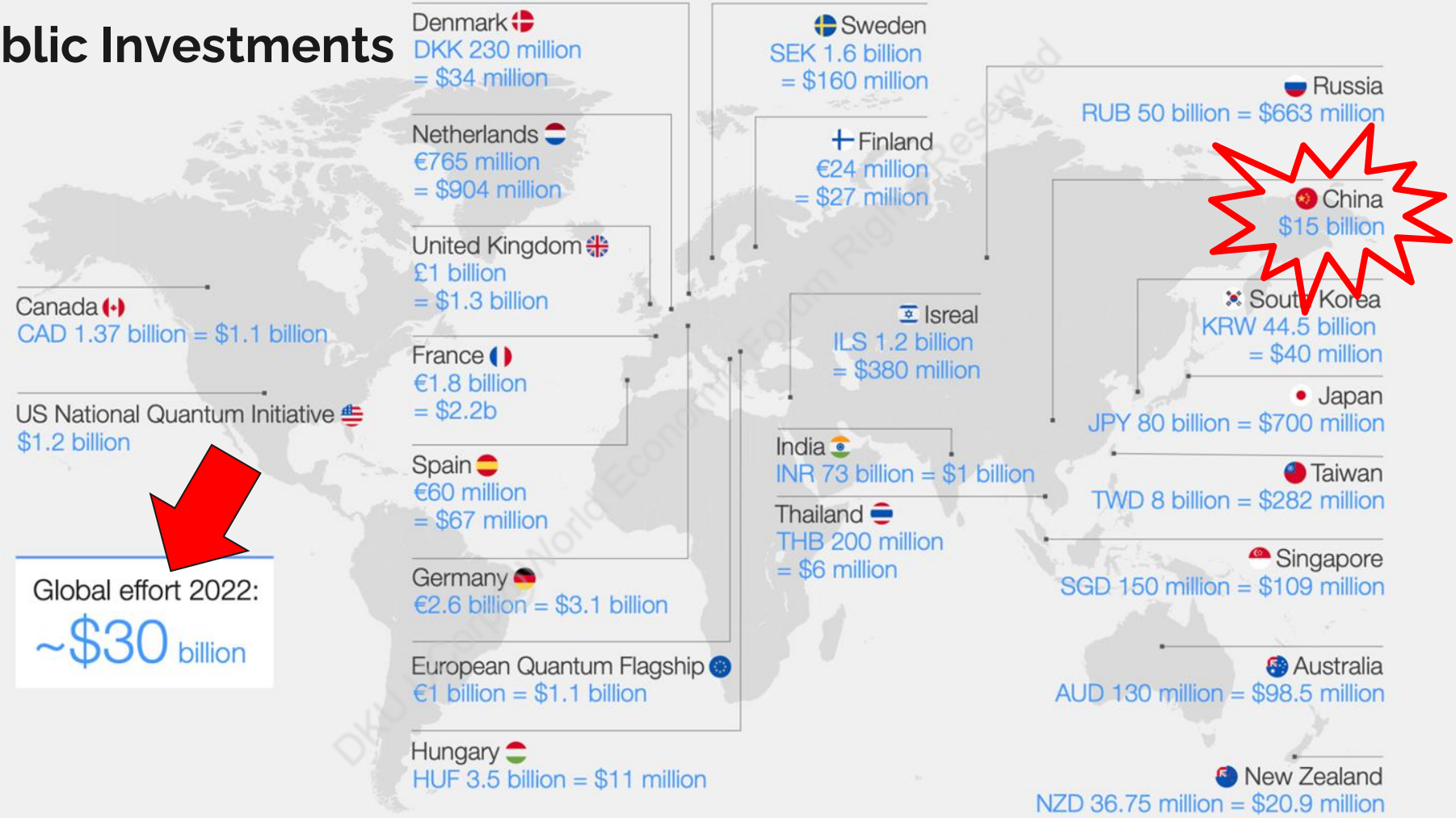
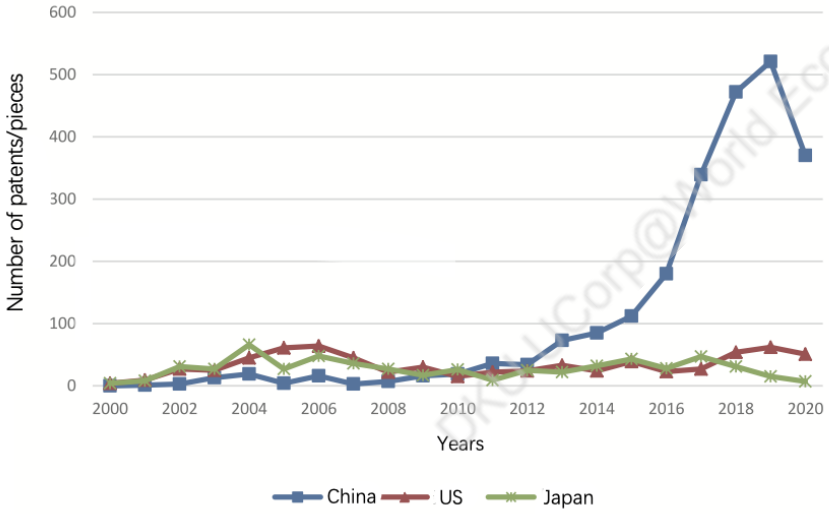
Public Investments

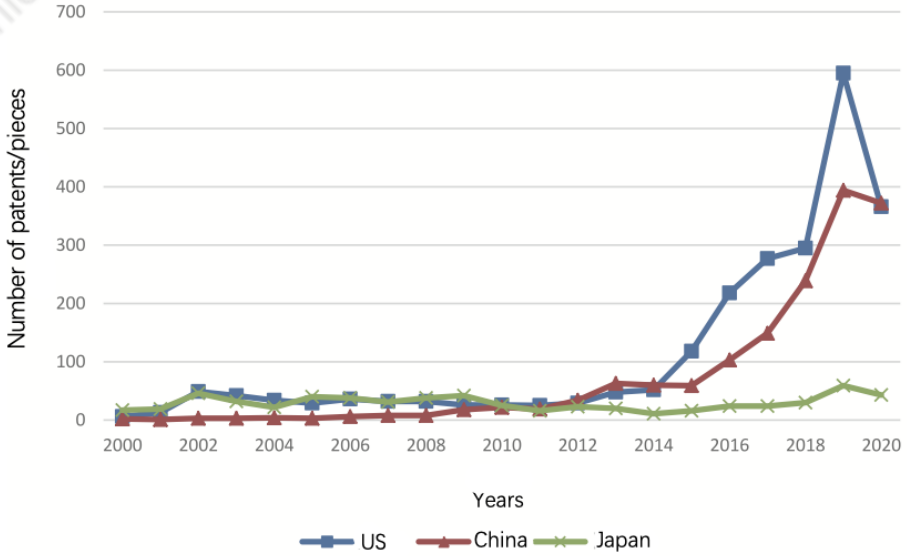


Patents

Quantum Communicaiton



Quantum computing



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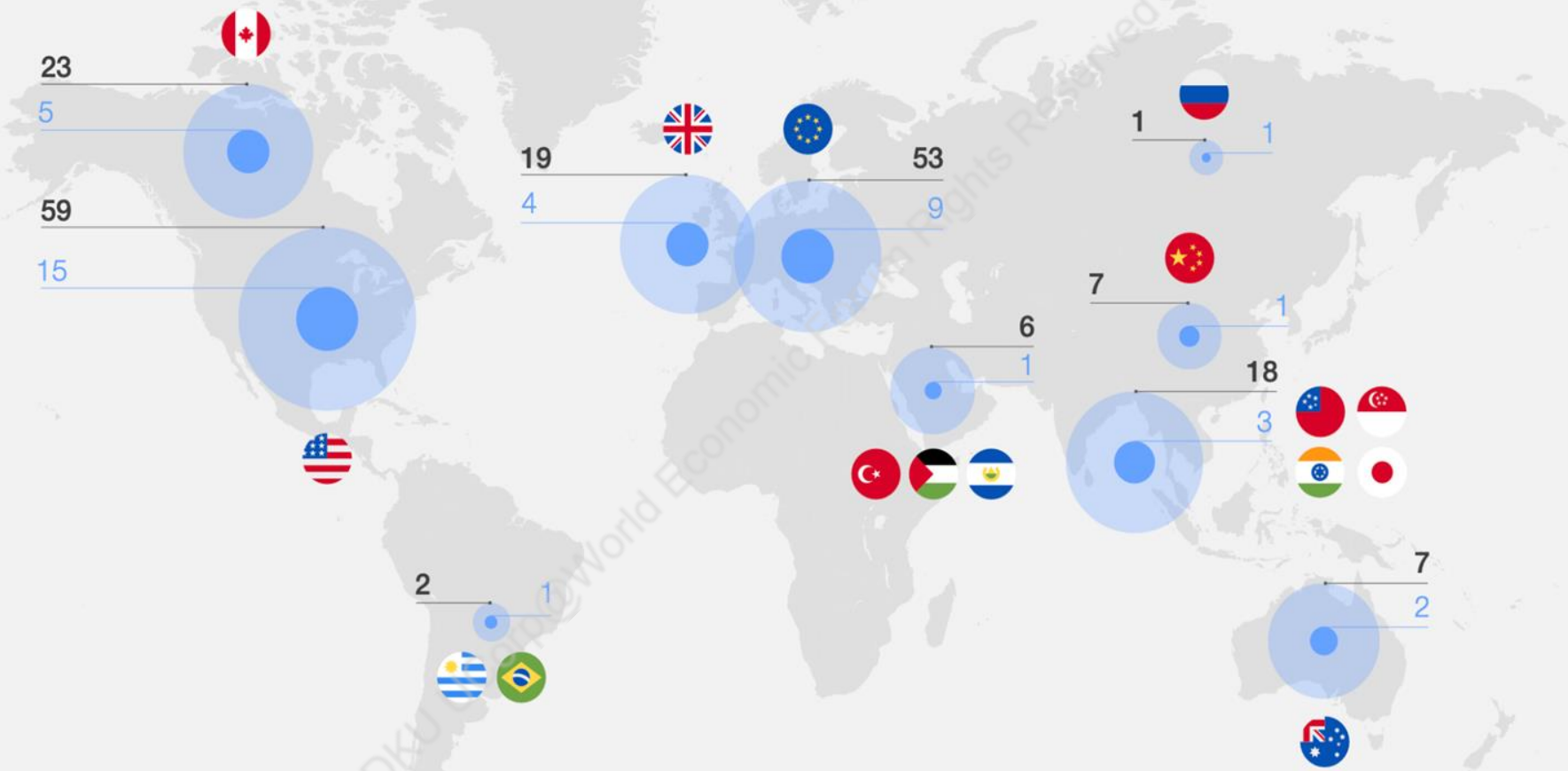
Private Sector



Public Policy of QTechnology

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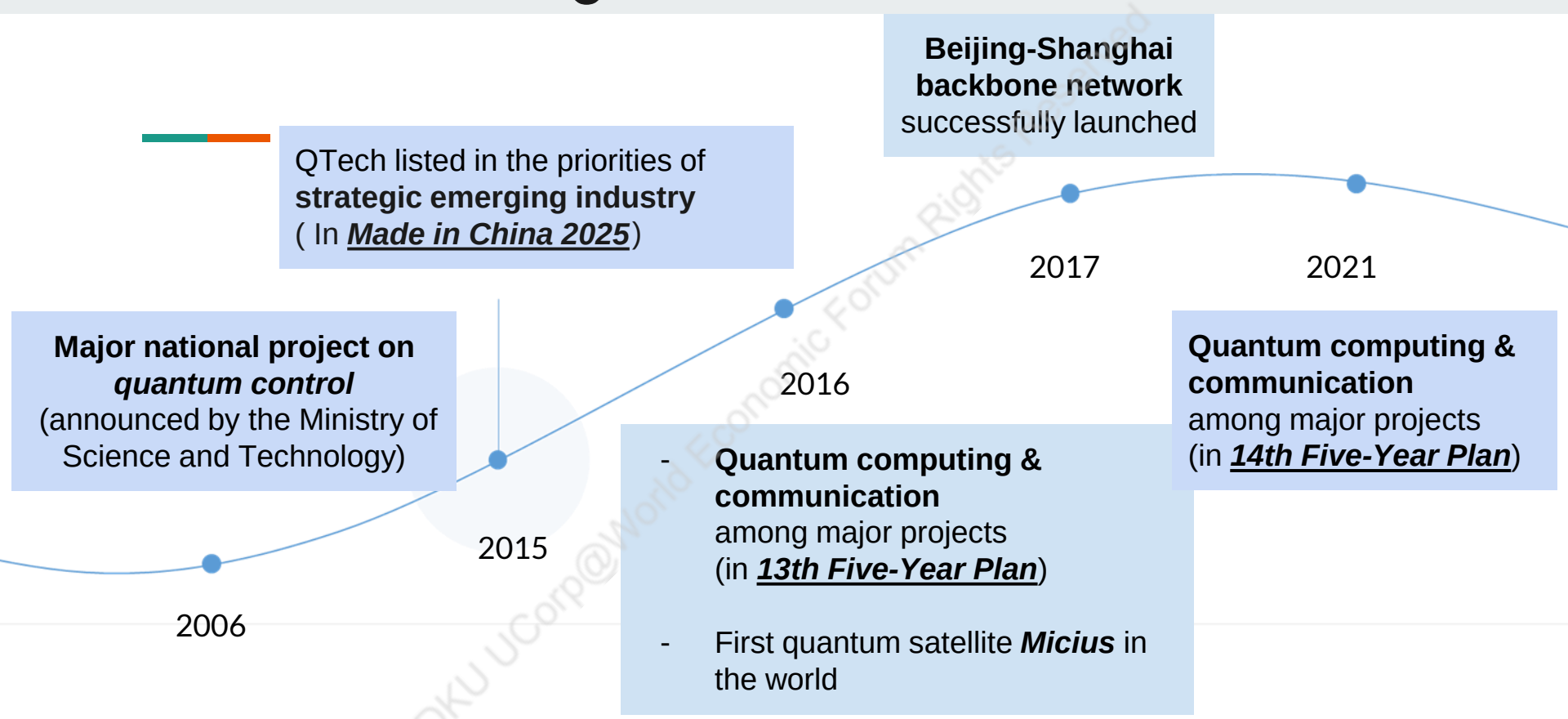
Timeline of Chinese government's milestones



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Chinses government's driving purpose

National strategy of **military-civil fusion**

Advancing Quantum Technology Services

Communication Security

Financial interest

Micius & Beijing-Shanghai
Quantum communication line

military applications

Quantum Financial Services Platform

Defense market share of more than 70%
(*Implementation Plan for the New Old Energy Conversion Major Project in Shandong Province*, 2018)

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Chinese government's projects

Table 1. Quantum information projects in China.

Year	Project	Funding agency	Total estimated amount (USD)	Notes
1998–2006	Minor projects mixed with other fields	NSFC	10 million	Early stage
2006–2010	1. Quantum control	1. MOST	150 million	The 11th five year plan
	2. Single quantum state detection and interaction	2. NSFC		
	3. Long distance quantum communication	3. CAS		
	4. Key technology research and verification of quantum experiments at space scale	4. CAS		
2011–2015	1. Quantum control	1. MOST	490 million	The 12th five year plan
	2. Quantum metrology	2. NSFC		
	3. National major scientific research instruments and equipment development	3. NSFC		
	4. Quantum experiments at space scale	4. CAS		
	5. Coherent control of quantum systems and metroloy physics in atomic systems	5. CAS		
	6. Quantum secure communication backbone	6. NDRC, CAS etc		
2016-now	1. Quantum control and quantum information	1. MOST	337 million	The 13th five year plan

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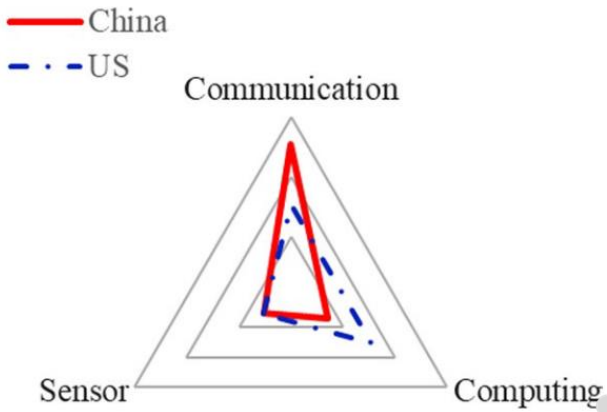
Kania, "China's Quest for Quantum Advantage—Strategic and Defense Innovation at a New Frontier."

Chinese government's main interests



Jang, Choung, and Kang, "Knowledge Production Patterns of China and the US."

Quntumn Communication

- the first that comes into application
- Most interested one

Quntumn Computation

- Taking the lead role worldwide
- Rising fast
- Still lack further development

Quntumn Sensing

- Starting late
- Immature standards

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Active Provinces

- Anhui, Jiangsu, Shanghai, Shandong,

  Shenzhen, Guangdong

  Beijing, Hebei, Tianjing

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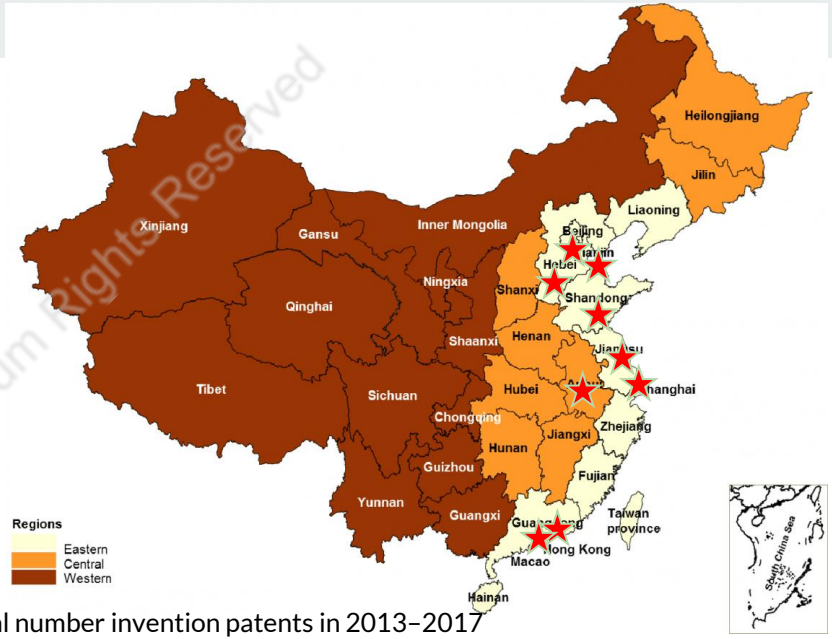
Active Provinces

Provinces	Total	u	i	g	ug	ig	ui	uig
Jiangsu	605,287	114,986	493,189	8,041	2,746	2,812	5,672	301
Guangdong	480,402	49,796	433,618	9,192	4,048	3,439	5,103	386
Beijing	366,192	72,367	279,721	35,100	1,958	11,127	8,517	606
Anhui	246,746	21,483	225,984	3,847	2,016	1,770	823	41
Shandong	220,948	44,292	173,949	6,560	382	1,551	2,016	96
Zhejiang	209,594	49,972	159,696	3,781	445	1,450	2,033	73
Shanghai	201,458	48,465	148,702	10,346	1,463	1,408	3,242	58
Sichuan	158,214	31,136	123,869	6,201	438	1,305	1,290	41
Tianjin	114,302	25,636	88,034	2,714	292	948	884	42
Hubei	111,654	37,916	73,659	3,166	536	938	1,664	51
Shaanxi	91,136	41,801	47,540	4,147	359	919	1,152	78
Henan	86,207	24,166	62,039	1,679	189	742	793	47
Chongqing	80,891	16,517	64,874	1,360	556	604	734	34
Guangxi	80,665	21,728	57,060	3,023	100	535	533	22
Hunan	78,289	24,922	53,627	1,175	91	427	940	23
Fujian	69,593	16,760	51,480	2,504	241	238	688	16
Heilongjiang	51,691	27,022	23,612	1,691	241	66	337	10
Liaoning	41,590	14,945	23,908	3,438	51	264	396	10
Hebei	37,717	10,148	27,268	1,131	137	258	453	18
Guizhou	33,109	6,111	26,877	1,105	55	567	369	7
Jiangxi	24,716	8,401	15,984	895	45	149	381	11
Yunnan	23,714	8,212	15,119	1,638	175	617	499	36
Shanxi	20,550	7,988	11,716	1,528	39	291	361	9
Gansu	12,640	4,226	6,397	2,445	50	136	252	10
Xinjiang	9,593	2,473	6,245	1,303	72	190	178	12
Ningxia	8,355	951	7,408	147	36	47	78	10
Inner Mongolia	7,886	2,082	5,787	341	88	103	146	13
Hainan	4,094	1,315	2,145	801	43	51	77	4
Jilin	4,080	1,849	2,255	73	18	12	72	5
Qinghai	3,200	387	2,338	663	55	75	71	13
Tibet	647	85	520	54	3	3	6	0

China provincial invention patent application quantity statistics



Classification of total number invention patents in 2013–2017

Classification	Criteria	Provinces
First	Above 300% of the average	Jiangsu Guangdong Beijing
Second	Between the average and the average of 300%	Anhui Shandong Shanghai Sichuan Zhejiang Tianjin
Third	Between 10% of the average and the average	Hubei Shaanxi Henan Chongqing Guangxi Hunan Fujian Heilongjiang Liaoning Hebei Guizhou Jiangxi Yunnan Shanxi Gansu
Fourth	Less than 10% of the average	Xinjiang Ningxia Inner Mongolia Hainan Jilin Qinghai Tibet

Zhuang et al., "Triple Helix Relationship Research on China's Regional University–Industry–Government Collaborative Innovation."

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Active Provinces

- Imbalanced distribution
- Interregional collaboration

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Horizontal Collaboration

Problems:

–Matthew effect

Beijing-Tianjin-Hebei Comprehensive Experimental Zone for Big Data

Action Plan of the Three Provinces and One City to Build the **Yangtze River Delta** Science and Technology Innovation Community (2022-2025)

Quantum Technology **Yangtze River Delta** Industrial Innovation Center

Quantum Confidential Communication Network Construction in **Yangtze River Delta**

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Vertical Collaboration

- Three-dimentional Collaboration: **Government - University - Industry**

Knowledge production in quantum technology
(Individual and collaborative research)

Domestic and international collaborative research in quantum technology

Jang, Choung, and Kang, "Knowledge Production Patterns of China and the US."

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Vertical Collaboration

- **The Quantum Science and Technology Yangtze River Delta Industrial Innovation Center**
  Suzhou Municipal People's Government and CEC Group
- **The Joint Laboratory of Quantum Communication Technology Application Research (Application Demonstration Center)**
  is jointly sponsored by China Xiongnu Group Digital City Technology Company Limited, Xiong'an New Area Smart City Innovation Consortium, and China United Network Communications Co.
- **Quantum Information Network Industry Alliance (QIIA)**
  - Ministry of Industry and Information Technology
  - Initiated by universities, research institutions, startups, technology companies and information and communication companies

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Vertical Collaboration

- Collaborative knowledge production by research actors

Research actors	Sub-technology	China	US
University	Communication	1121	500
	Computing	287	494
	Sensor	220	182
Research Institute	Communication	85	176
	Computing	40	134
	Sensor	27	43
Industry	Communication	14	77
	Computing	4	103
	Sensor	2	15

Jang, Choung, and Kang, "Knowledge Production Patterns of China and the US."

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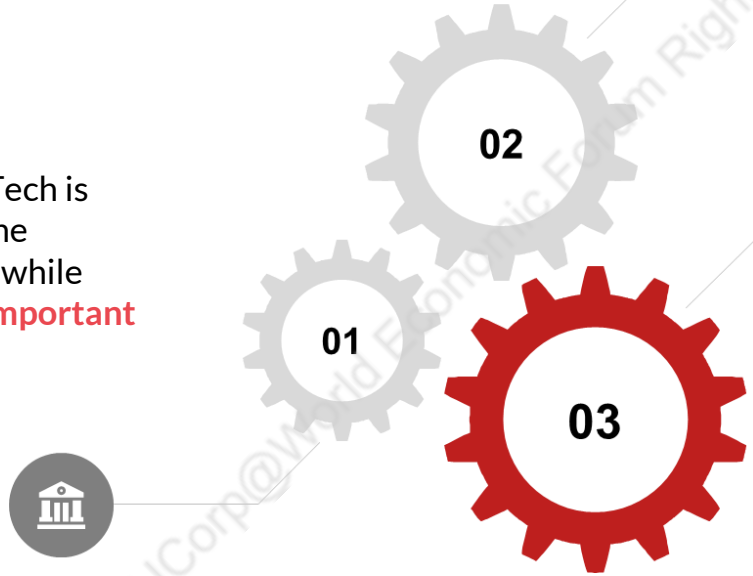
Bridge

The development of QTech is highly contributed by the **collaborative research** while **government takes an important role** in it.

"service government"



More focused on **applied area**

However, Chinese government may need to put more efforts in the development of **basic science**.

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Private Sector of Quantum Technology

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Stakeholders

- Academia: University of Science and Technology of China, Tsinghua University
- Big tech firms: Alibaba, Baidu, Tencent, Huawei
- Startups: Origin Quantum, Quantum CTek , Qudoor

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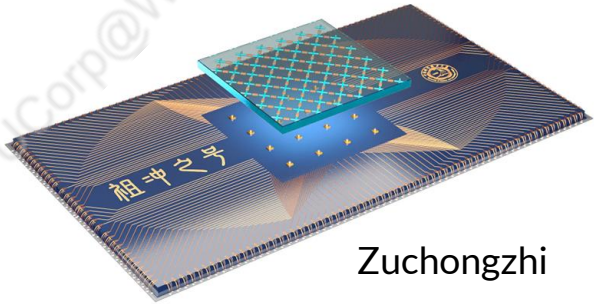
Milestones - Hardware

- 2020 - Satellite Micius realized quantum key distribution over 1,200 kilometers.
- 2021 - Zuchongzi and Jiuzhang 2.0 achieve "quantum supremacy" over classical computers

Micius



Zuchongzhi

Jiuzhang 2.0

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Quantum Software

Quantum control system & simulation platform from big tech firms

- Alibaba
  - Alibaba Cloud Quantum Development Platform
- Huawei
  - HiQ: Online development environment
- Baidu
  - Paddle Quantum: Quantum machine learning
- Tencent
  - TensorCircuit: Simulation of quantum circuit

Out of Lab now !

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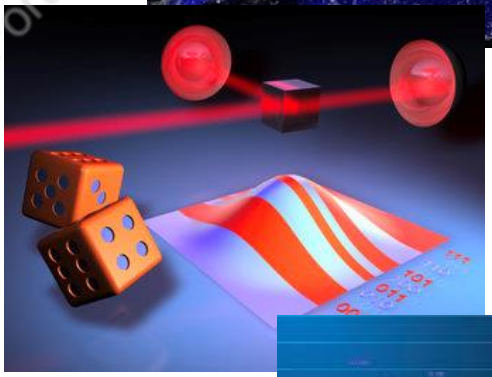
QTech in Finance

- ICBC(Industrial and Commercial Bank of China)
  - 2015 - Encrypted transmission of electronic file
  - 2021 - Apply quantum random numbers
- CCB (China Construction Bank)
  - "quantum option pricing algorithm"
  - financial markets and risk management



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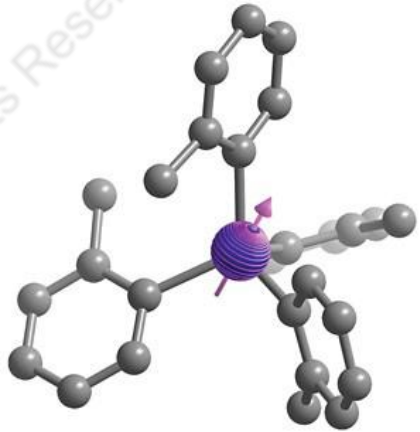
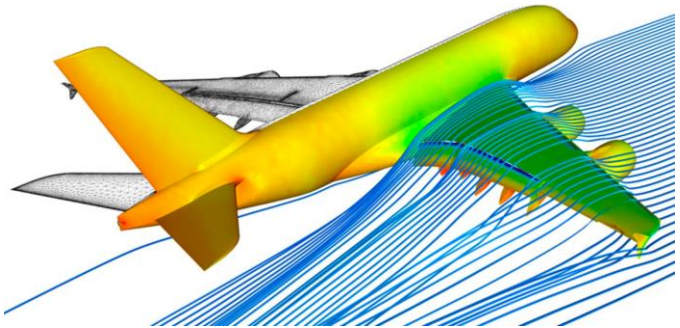
Applications in other scenarios

- Origin Quantum:
  - Quantum chemistry application - ChemiQ
  - Fluid Dynamics Simulation Software -QCFD
- Tencent:
  - Material simulation
  - Drug design and screening





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The Challenges of Developing Quantum Technology in China

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Overall Challenge

- The industrialization of QTech in China is still at the very primary stage
- Marketization mechanism has not yet been formed.
- Lack of mature business model and business opportunities
- Initial market size and user groups are very limited

- Combines many unusual specialized fields
- Interdisciplinary talents needed

- Caompared to the US, cooperation between agencies needs to be strengthened
- Among enterprises, universities and scientific research institutions
- Between enterprises

- Hard for China to import key parts

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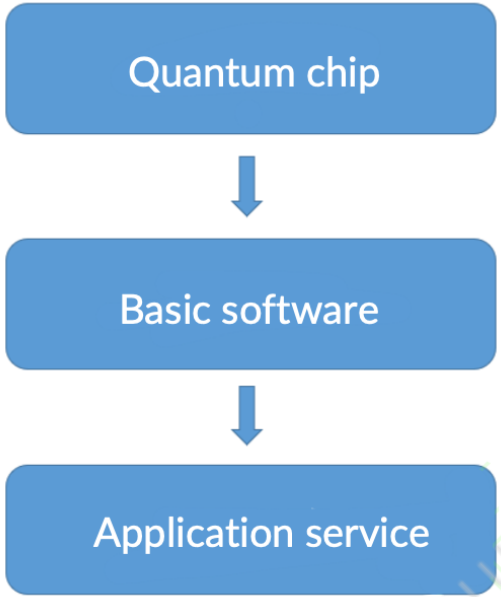
Quantum Computing

Industrial Chain of Quantum Computing



- One of the core components of a quantum computer

- For developers
- It provides software development environment, quantum programming framework and quantum computing library for quantum computing

Lagging behind

- User oriented
- It provides data analysis tools, materials design, medical pharmaceutical, artificial intelligence accelerated computing and other services

Previous slide

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Quantum Computing

- **Many links in the quantum computing industry chain is lagging behind**
- **Quantum chip**:
  - many technical routes are still under exploration,
  - there is a technology gap of 2~3 years compared to international advanced level
- **Basic software**:
  - Quantum programming language:
    - relatively few kinds
    - low application degree
    - Insufficient application of quantum technology
  - Quantum algorithm theory:
    - development in China is relatively late, still in its infancy

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Macro-environment factors

- Increasing price of materials
  - Parts: superconductors
  - Raw materials: aluminium, Silicon, Diamond, ion traps
- Covid-19 pandemic
  - Revenue of private companies (such as Quatum CTek) decrease
  - Less knowledge import

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Our conclusions

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Top 3 takeaways

1. China is rapidly becoming the world leader in Quantum Communications and Security
2. Challenges like high costs, lack of talent, and slow hardware development are an impediment in China's expansion in Quantum Sensing and Computing
3. Companies need to invest more in Quantum Computing and acquiring talent from academia, as the collaboration between these stakeholders has been limited, and the Chinese national interest is Quantum Communication

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