

IBM Research

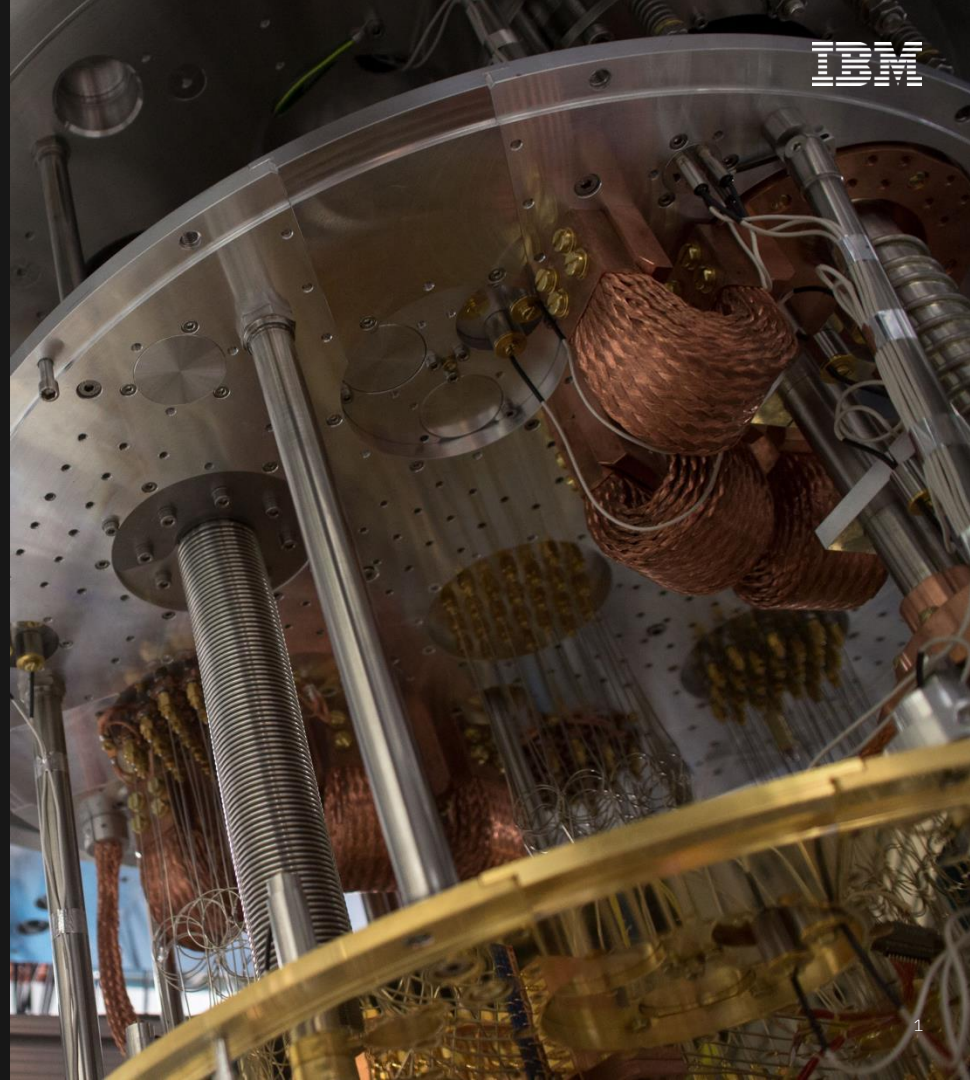
Quantum Computing Opportunities and Challenges

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IBM Q

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#IBMQ



About Me

Dr Peter Waggett

PhD in Rocket Science

Failed Astronaut

Over 25 years IT Research
Experience

Director of Research – IBM UK

Research Emphasis on Emerging
and Disruptive Technologies



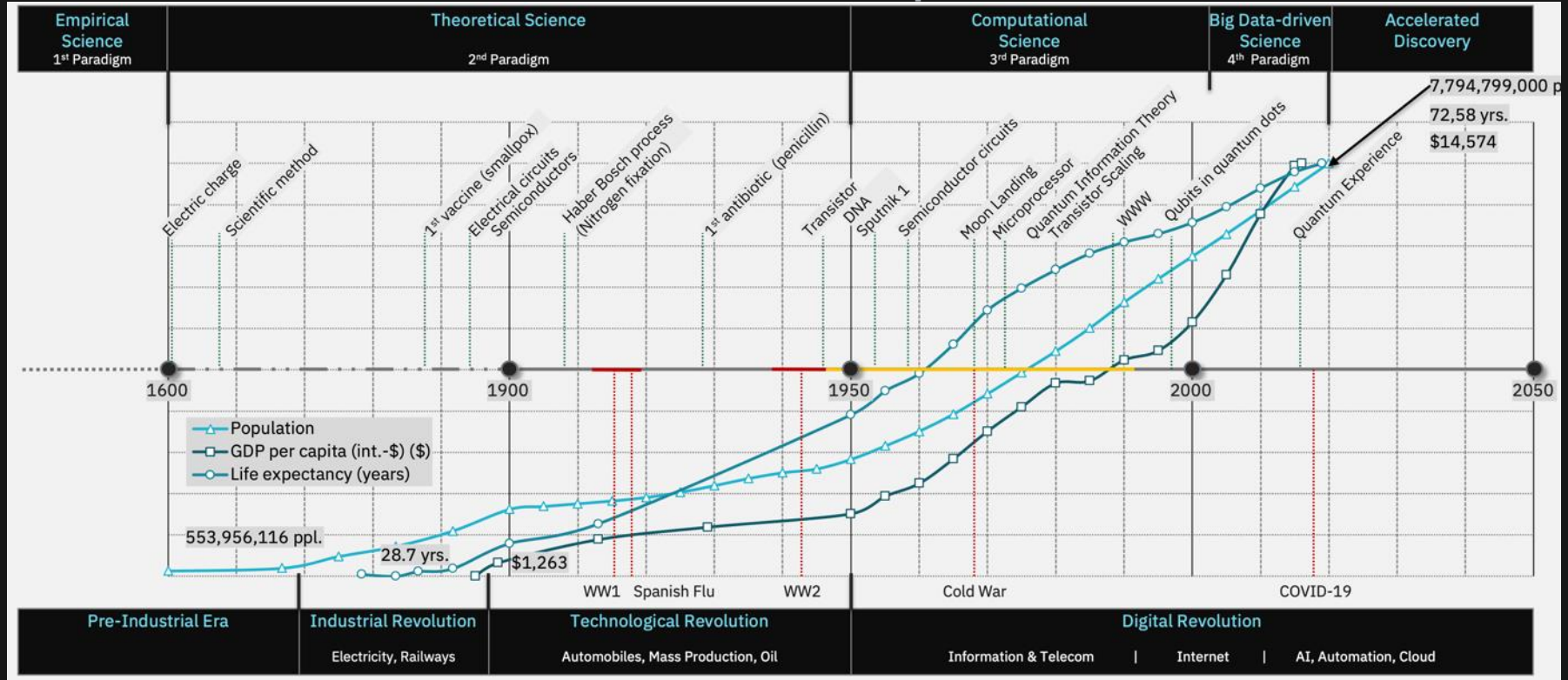
The urgency
of science
has never
been stronger
than it is now.

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The scientific method has been humanity's best model for discovery.

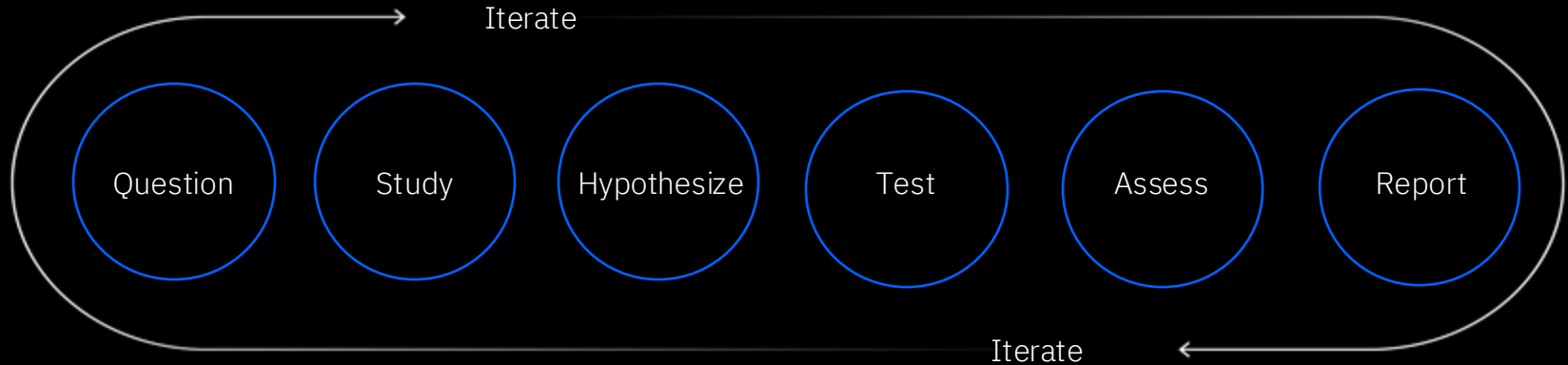
Science has solved some of the world's most difficult problems



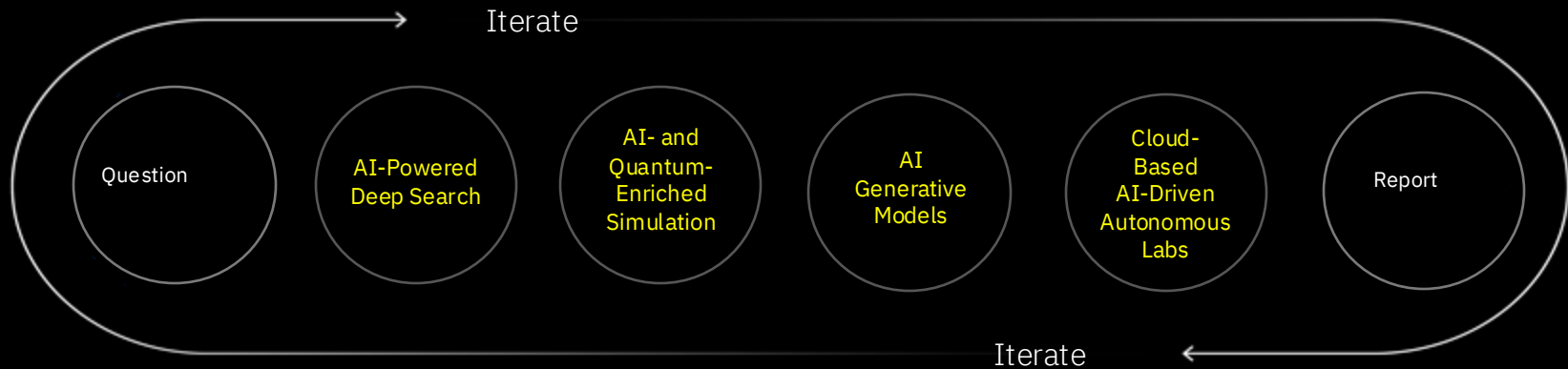
... and it has evolved over time and we are now entering a new paradigm of discovery.

1 st Paradigm	2 nd Paradigm	3 rd Paradigm	4 th Paradigm	
Empirical Science	Theoretical Science	Computational Science	Big data-driven Science	Accelerated Discovery
Observations Experimentation	Scientific laws Physics Biology Chemistry	Simulations Molecular dynamics Mechanistic models	Big data Machine learning Patterns Anomalies Visualization	Scientific knowledge at scale AI generated hypotheses Autonomous testing
Pre-Renaissance	~1600s	~1950	~2000	2020

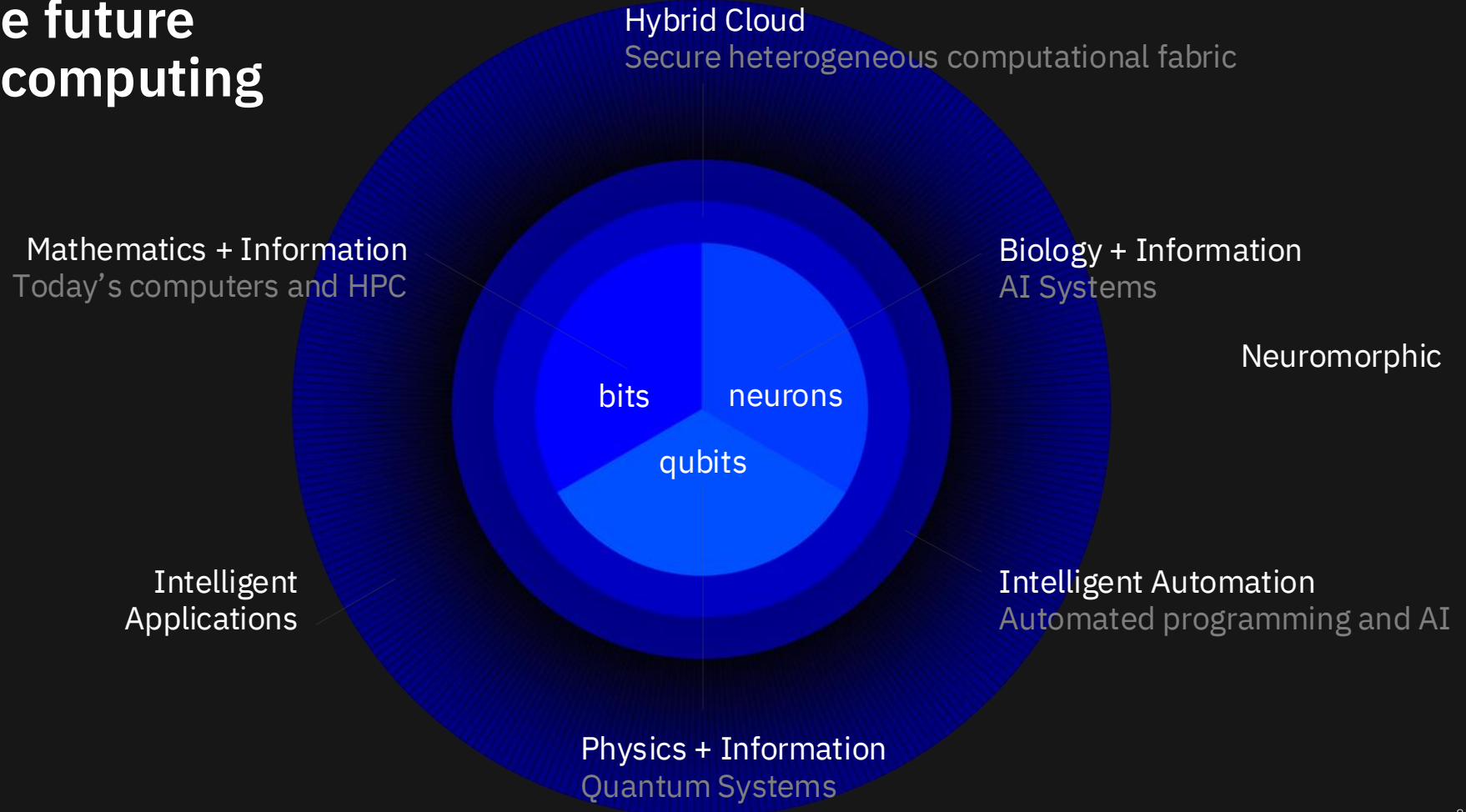
We supercharge the scientific method ...



... to create the components of an accelerated discovery workflow.



The future of computing



“I’m not happy with all the analyses that go with just the classical theory, because nature isn’t classical, dammit, and if you want to make a simulation of nature, you’d better make it quantum mechanical ...”

**Richard P. Feynman
Department of Physics,
California Institute of Technology**

**International Journal of Theoretical Physics,
Vol 21, Nos. 6/7, 1982**



Opportunities with Quantum Computing

Qbits

New Operations

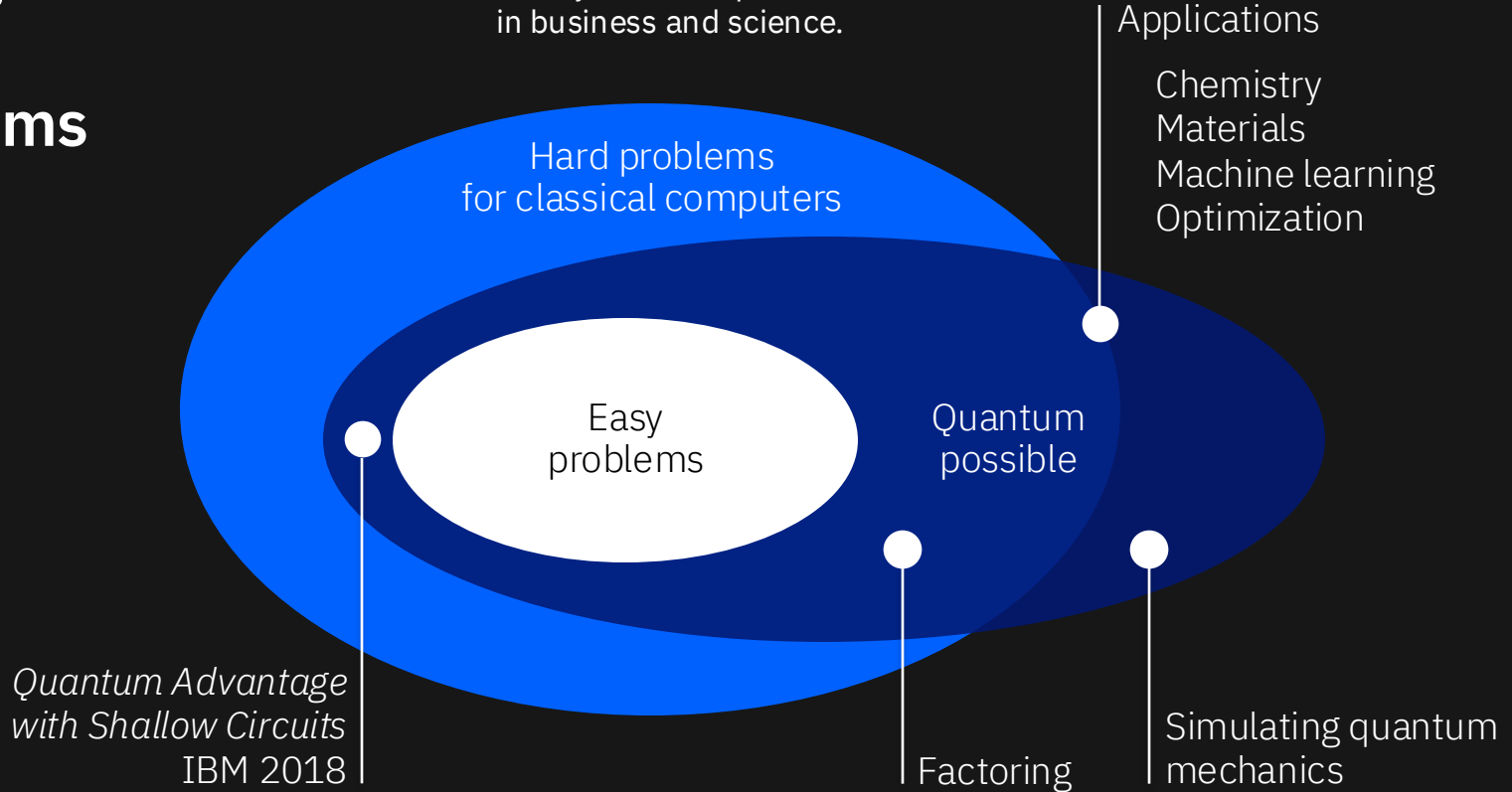
- Superposition
- Entanglement
- Decoherence
- Interference

New Use Cases

- Chemistry/Materials
- Pharmaceuticals
- Machine learning

Hard versus easy problems

Quantum computing may provide a new path to solve some of the hardest or most memory intensive problems in business and science.





HARTREE NATIONAL CENTRE FOR DIGITAL INNOVATION



Science and
Technology
Facilities Council

Hartree Centre



Development Roadmap

2019

2020

2021

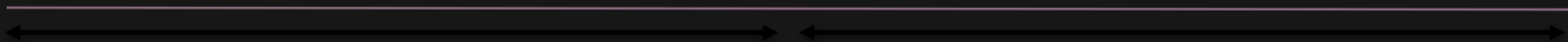
2022

2023

2024

2025

2026+



Enterprise Clients

Use case exploration
Problem mapping
Skills building

Workflow integration
Application development
Skills building

Model developers

Qiskit application modules

Quantum model services

Natural Sciences	Finance
Optimization	Machine Learning

Algorithm developers

Natural Sciences	Finance
Optimization	Machine Learning

Prebuilt quantum runtimes

Prebuilt quantum + HPC runtimes

Kernel developers

Circuits

Qiskit Runtime

Dynamic circuits

Circuit libraries

Advanced control systems

Quantum systems

Falcon
27 qubits

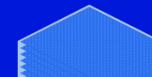
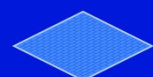
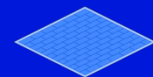
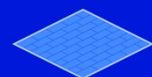
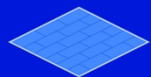
Hummingbird
65 qubits

Eagle
127 qubits

Osprey
433 qubits

Condor
1121 qubits

Beyond
1K - 1M+ qubits



IBM Cloud

Circuits

Programs

Models

Quantum Volume

Qbits x Error Rate

Quantum Errors

Sources

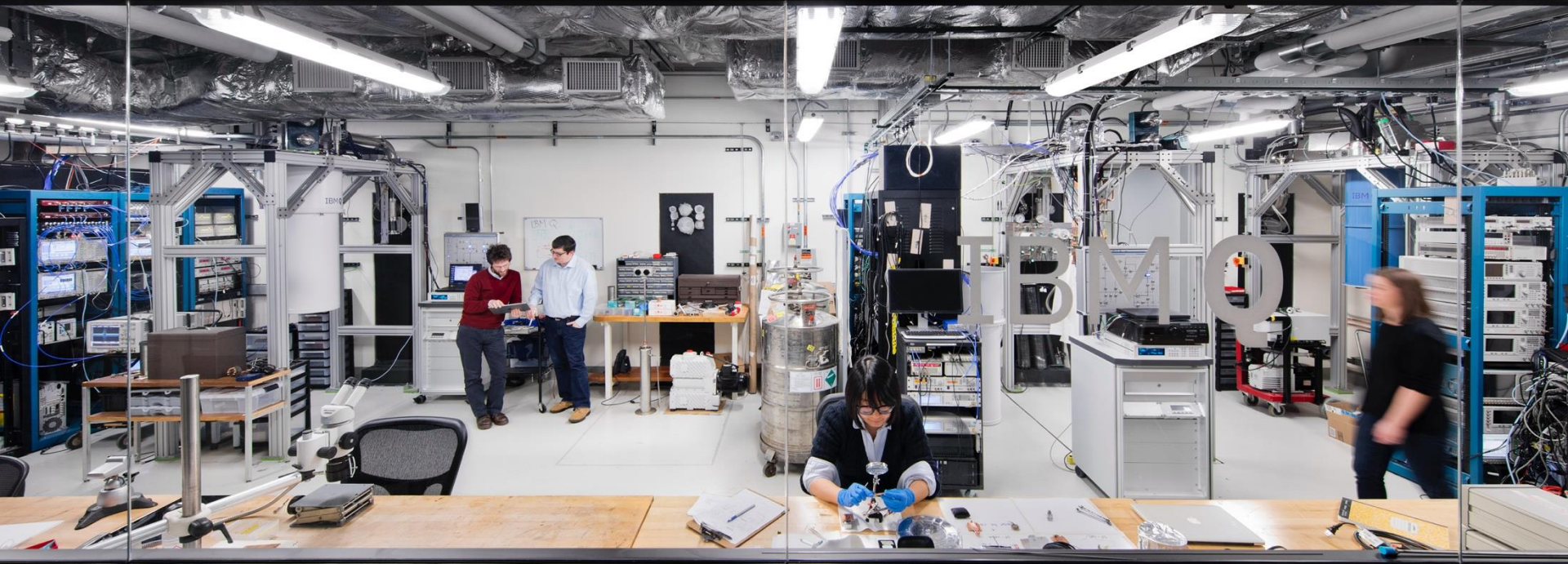
- Cosmic Rays
- Thermal Instabilities
- Etc

Quantum Error Mitigation and Correction

Environments Like Boulby?

Error Mitigation

Error Correction



Thank you

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