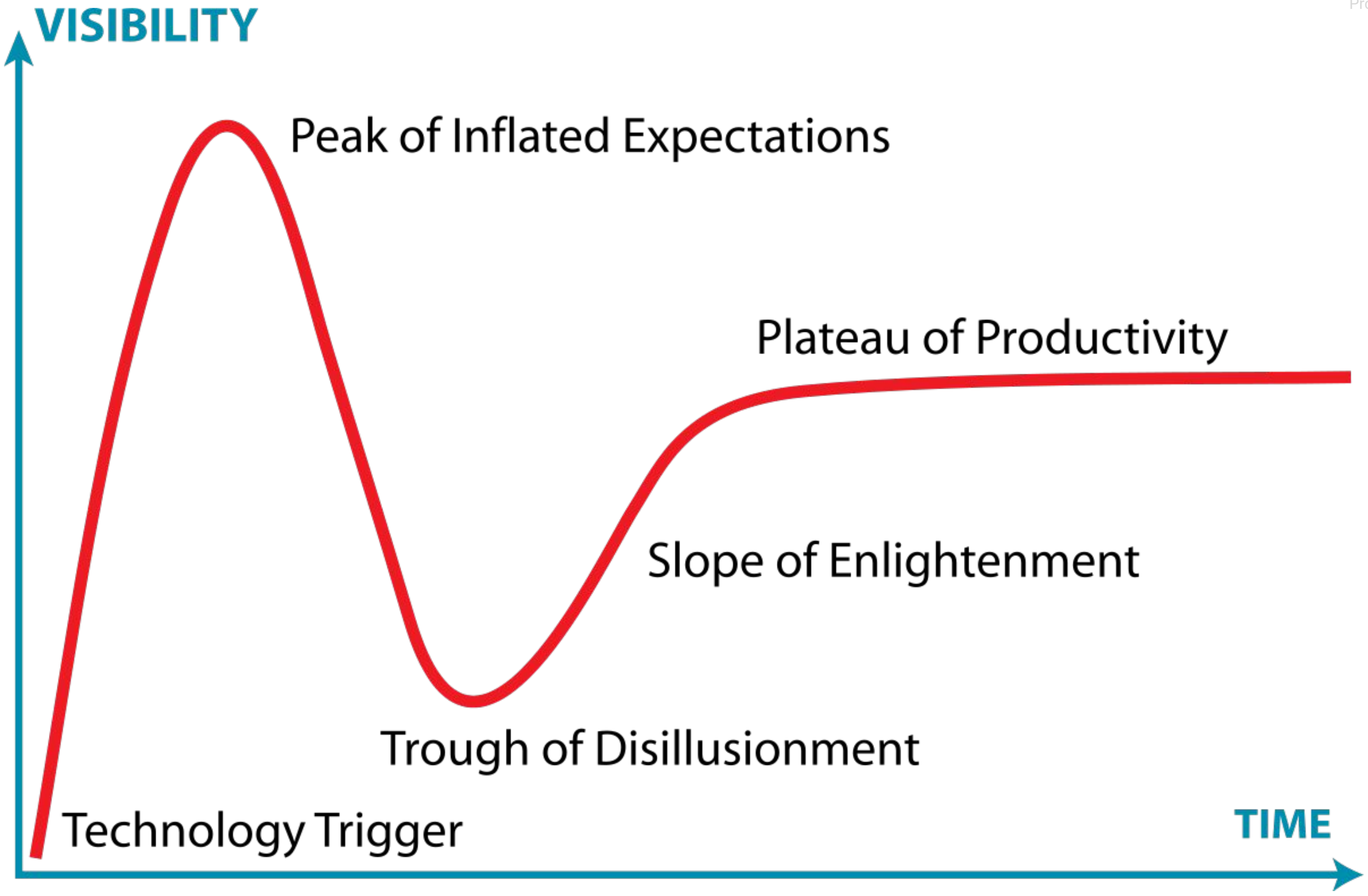
Quantum AI

Classical and Quantum Machine Learning

Annalisa Pawlosky, PhD
Staff Research Scientist
Google

Google

Menu



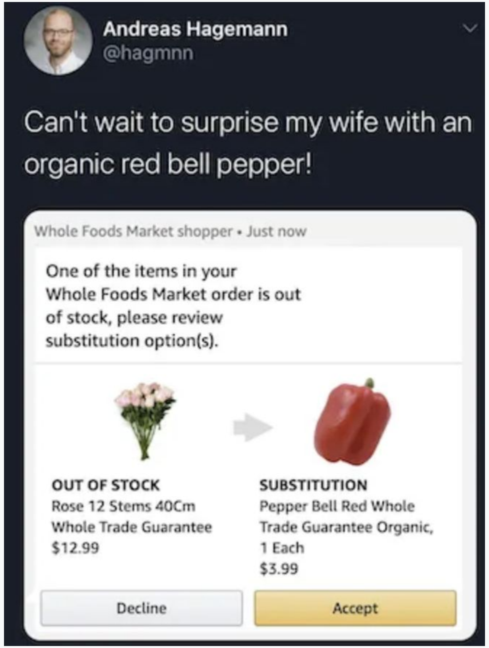
https://en.wikipedia.org/wiki/Hype_cycle

Promise of ML

ChatGPT

openai.com

Peril of ML



x.com, medium.com

Solutions

Good Data

Good Data Analysis Guide (Patrick Riley)

Awareness (Roadblocks, Biases, Limitations, Hallucinations)

*be your own greatest critic

Building your own

Design

Machine Learning can ***not*** fix bad experimental design.

Data

Expert labeling data is important, but dirty training data is very useful.

Limitations

Biases are everywhere. Know what yours are.

Training

Training/testing data spilt defines the question. Understand the question.

Patterns

Humans and computers find patterns that are ***not*** there.

Predictions

When possible, test. Evaluation Frameworks are critical.

Don’t lose sight of your ground truth.

Using somebody else's

Model selection

Know the source. How was it trained? Tested? Validated?

Prediction

Ask for evidence.

Restrict data sources.

Use RAG (retrieval-augmented generation) when appropriate (large data).

Fine-tune (specific use case).

Evaluation

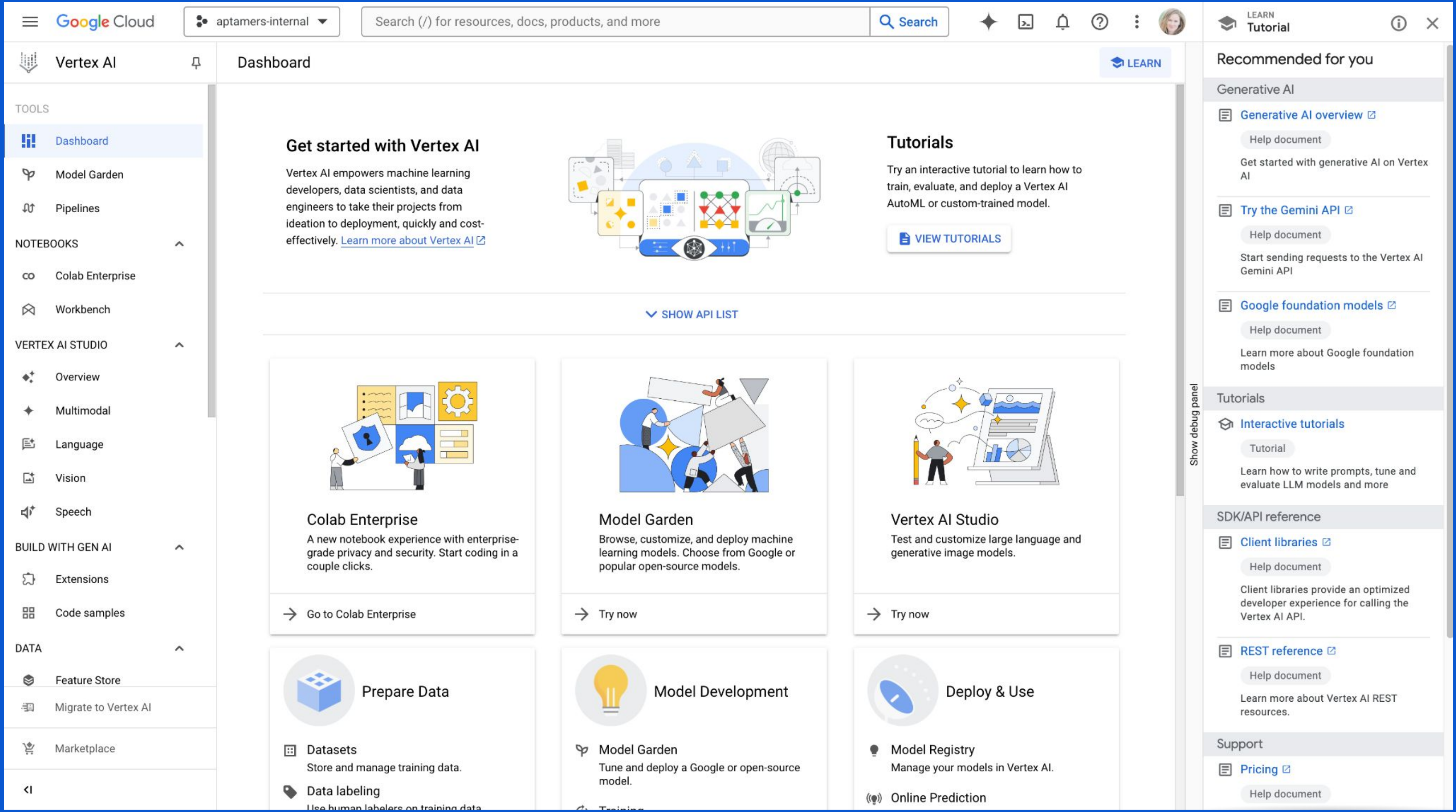
Great and broader the testing base, the more rotational invariant your predictions become.

Optimize or manage prompt engineering.

All the data. All the questions.

Multimodal machine learning with Google Cloud

Vertex AI. The home to Cloud's AI solutions in one place.


Google Cloud
aptamers-internal
Search (/) for resources, docs, products, and more
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Google helps to accelerate research in astrophysics

2019

Using TensorFlow, Google's open-source AI platform, Gema created a program called **Deep Asteroid**.

Deep Asteroid helps scientists with asteroid tracking and classification.

[AI in Astronomy and NASA Asteroid Tracking - Google]

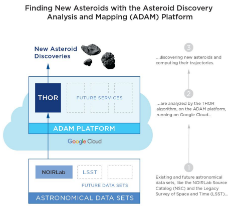
2020

Rubin Observatory to host its Interim Data Facility (IDF) on Google Cloud

[Google Cloud fuels new discoveries in astronomy]

2022

Google Cloud helps ADAM and THOR find asteroids



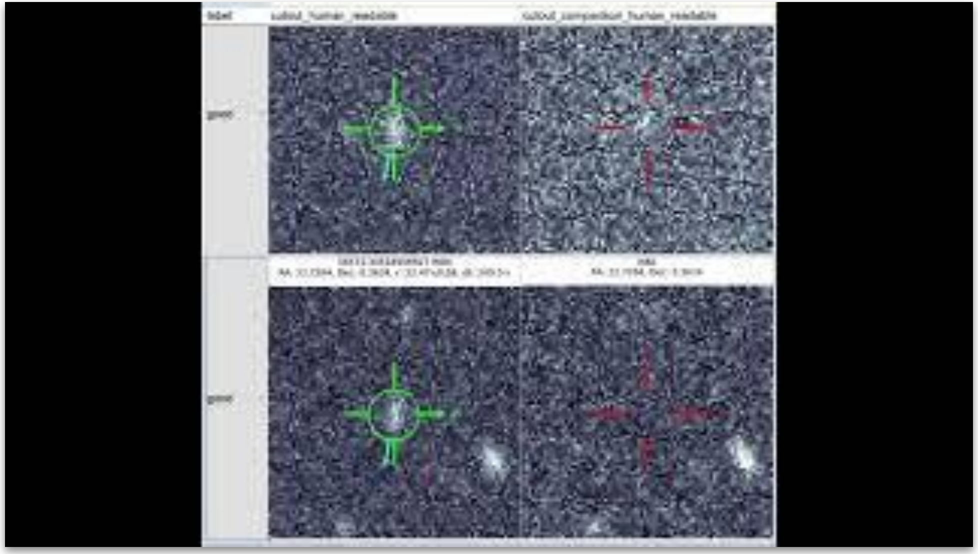
[Google Cloud helps ADAM and THOR find asteroids]

Google helps to accelerate research in astrophysics

2024

Google Cloud helped the **Asteroid Institute** scale up an algorithm it built to identify potential asteroids — and found nearly 30,000 candidates in just a few weeks.

They plan to open source the model training data to help other scientists.

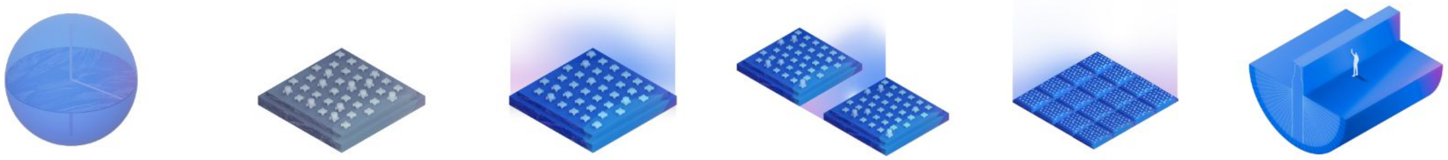


A visual sample of validating discoveries, which still requires manual review of images of the observations. Individual observations are classified and labeled, depending on if the detection is real and a reasonable fit for the orbit of the candidate discovery.

Trends in Quantum Machine Learning

Our quantum computing roadmap

Our focus is to unlock the full potential of quantum computing by developing a large-scale computer capable of complex, error-corrected computations. We're guided by a roadmap featuring six milestones that will lead us toward top-quality quantum computing hardware and software for meaningful applications.



MILESTONE 1

BEYOND CLASSICAL

Physical Qubits: 54
Logical Qubit Error Rate: -

2019

MILESTONE 2

QUANTUM ERROR CORRECTION

Physical Qubits: 10^2
Logical Qubit Error Rate: 10^{-2}

2023

MILESTONE 3

BUILDING A LONG-LIVED LOGICAL QUBIT

Physical Qubits: 10^3
Logical Qubit Error Rate: 10^{-6}

2025+

MILESTONE 4

CREATING A LOGICAL GATE

Physical Qubits: 10^4
Logical Qubit Error Rate: 10^{-6}

MILESTONE 5

ENGINEERING SCALE UP

Physical Qubits: 10^5
Logical Qubit Error Rate: 10^{-6}

MILESTONE 6

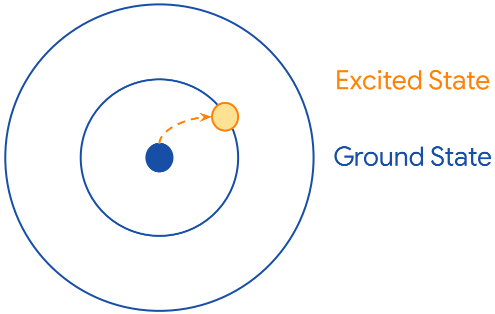
LARGE ERROR-CORRECTED QUANTUM COMPUTER

Physical Qubits: 10^6
Logical Qubit Error Rate: 10^{-13}

Machine Learning in Natural Sciences

Quantum and classical machine learning in physics and chemistry is a rich and vivid field, ranging from learning quantum states to quantum channels.

Learning Quantum States

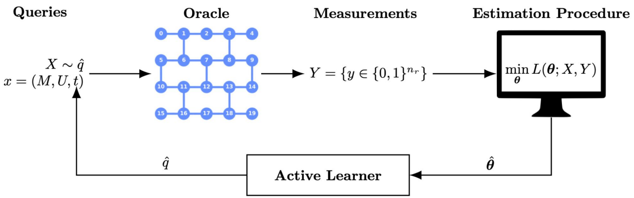


Electron correlation, Matchgate states, Stabilizer States, Phase States, Gibbs States

[Quantum convolutional neural networks | Nature Physics]

Learning Quantum Observables

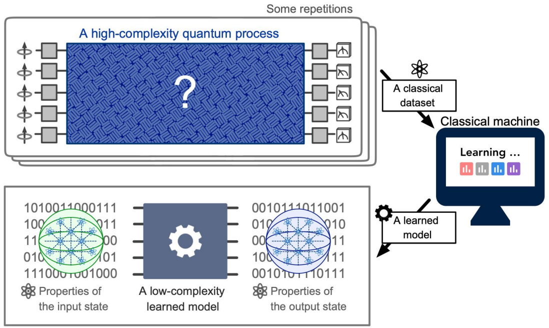
$\mathrm{tr}(\rho O)$



Schematic of Hamiltonian learning with an active learner

[Phys. Rev. Research 5, 033060 (2023) - Active learning of quantum system Hamiltonians yields query advantage]

Learning Quantum Processes



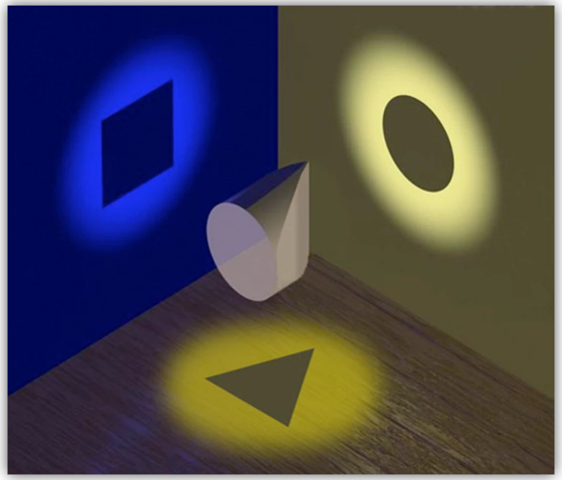
Learning to predict an arbitrary unknown quantum process $\mathcal{E}$

[PRX Quantum 4, 040337 (2023) - Learning to Predict Arbitrary Quantum Processes]

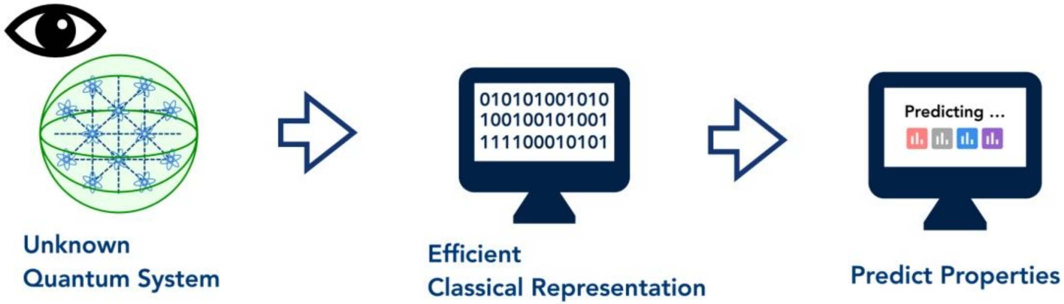
Google

Advantage of Classical Learning in Natural Sciences

Classical machine learning is efficient in understanding essential properties of quantum states and quantum processes under controlled error ('shadow tomography')



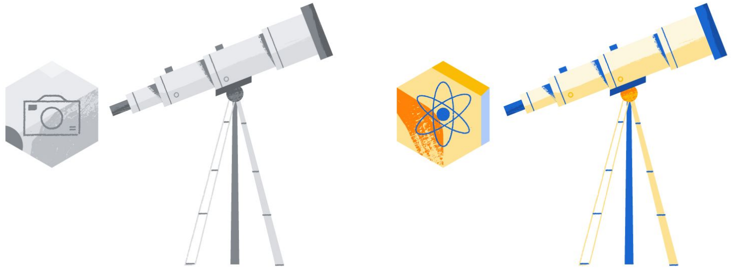
Computing "classical shadows" is analogous to projecting a 3-D object into two dimensions along multiple axes

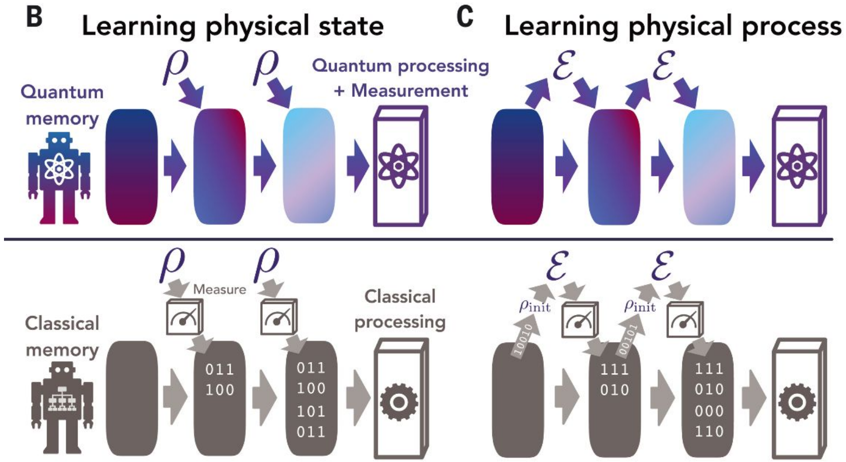


[Predicting many properties of a quantum system from very few measurements | Nature Physics](#)
[PRX Quantum 4, 040337 (2023) - Learning to Predict Arbitrary Quantum Processes](#)

Advantage of Quantum Learning in Natural Sciences

There are quantum datasets that are hard to learn for classical models and easy to learn for quantum models **using exponentially fewer data** = reduced sample complexity





Quantum advantage in learning from experiments | Science

Start Quantum with Google Cloud

Classical Simulation of Quantum

Google TPUs

Quantum-inspired simulation with **Cirq**, **OpenFermion**, **TensorFlow Quantum** on GPU or TPU

Nvidia GPUs

Cuda-Q or **cuQuantum** for highly performant multi-GPU multi-node solution for quantum circuit simulation

Quantum Computing

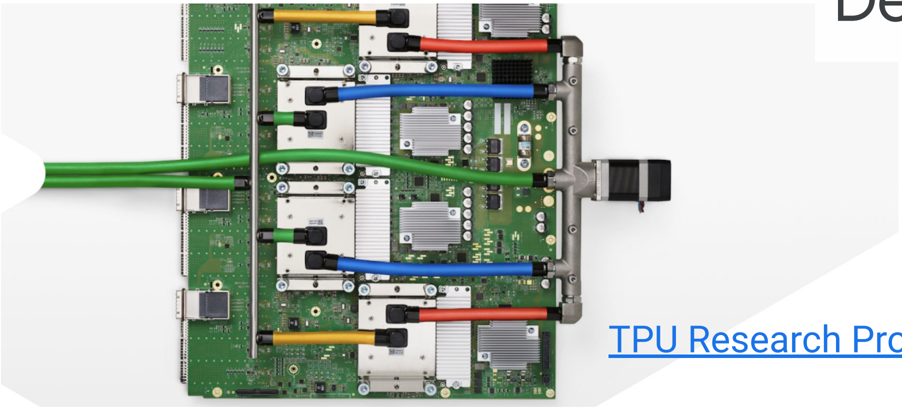
IonQ

Run quantum circuits on the 11-qubit, fully connected **trapped-ion** Ytterbium systems

Alice & Bob

Cat qubit quantum chip with a maximum bit-flip time of over 7 minutes

Dessert



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PhD Fellowship Program

Google Research

Research scholar program

Research Scholar Program (funding, research at Google)

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XPRIZE Quantum Applications | Google Quantum AI

Quantum AI

XPRIZE Quantum Applications | Google Quantum AI is a 3-year, $5M global competition designed to advance the field of quantum algorithms towards pro-society real-world applications, with funding from Google.org.

Google Cloud Quantum AI Applications - apawlosky@google.com