LIVE SESSION

QUANTUM MACHINE LEARNING WORKSHOP

ON 16-JUL-2022 @ 9 AM IST - ONLINE LIVE DELIVERY

REGISTER FREE

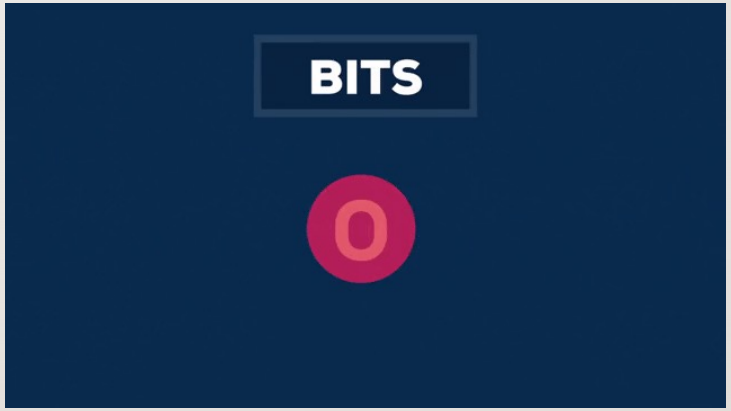
HTTPS://FORMS.GLE/WRNBGSXGEUAAD5DX7

PRASANNA VENKATESH

AI AND CLOUD EVANGELIST

CLASSICAL COMUPTERS

- Basis of classical computers
- BITS
  - Either Zero or One
  - Only one state at a time



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SIMPLE COIN FLIP

- Is it Head? Or Tails?
- What is the value when it is in REST?
- What is the value when it is tossed?

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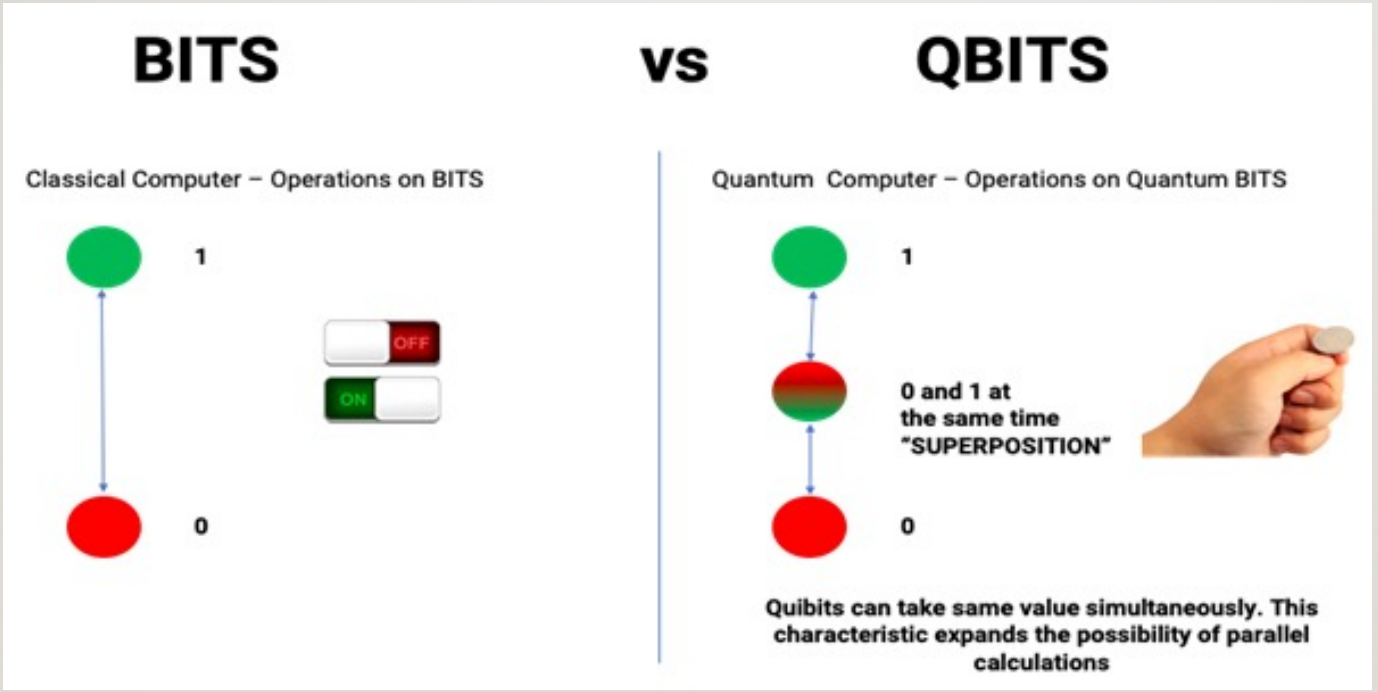
SIMPLE COMPARISON

- **Coin at stabele stage on the hand – compared to classical computers BITS.**
  - At any point only one state is possible.
- **Coin at the tossed stage – quantum computing super position stage.**
  - At any point two posible values at the same time for a bit
  - Quantum Bit
    - **QuBIT**

BITS VS QUBITS



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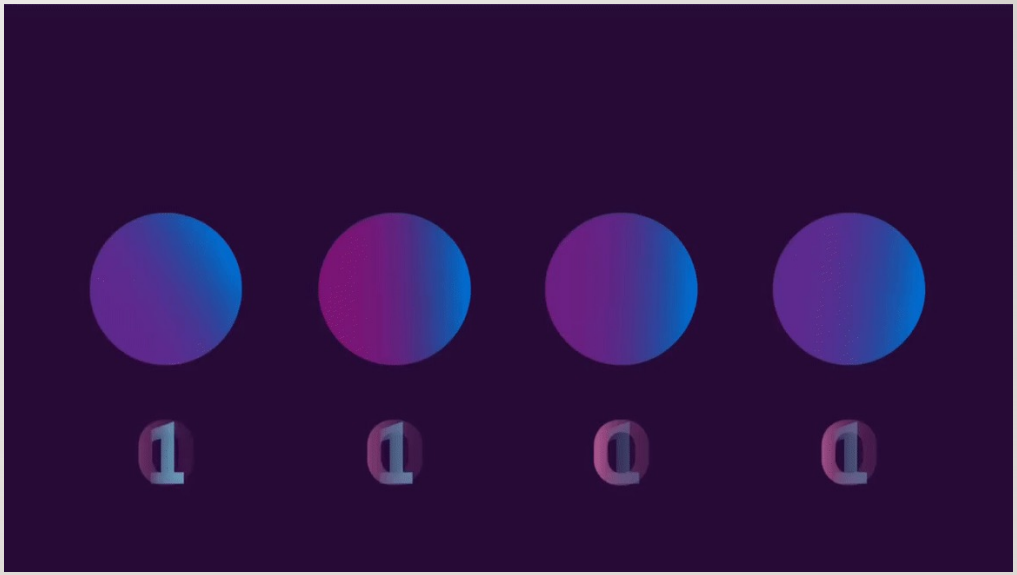
QUBIT – SUPER POSITION STATE

- At the same time has both zero and one.
- Image shows 4 qubits and the value changes both 1 and 0 at the same time.
- This state is called super position state



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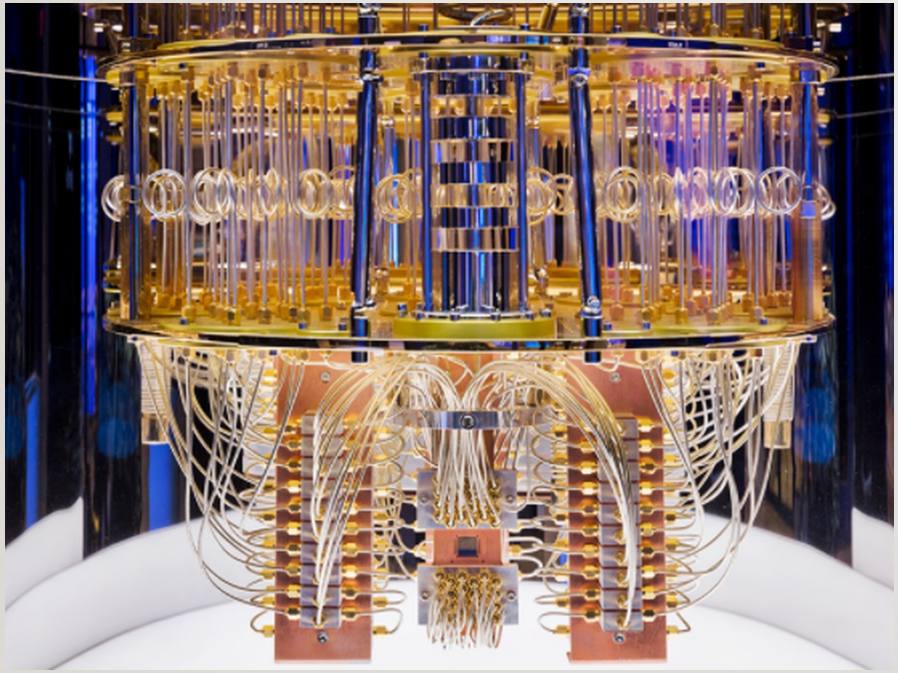
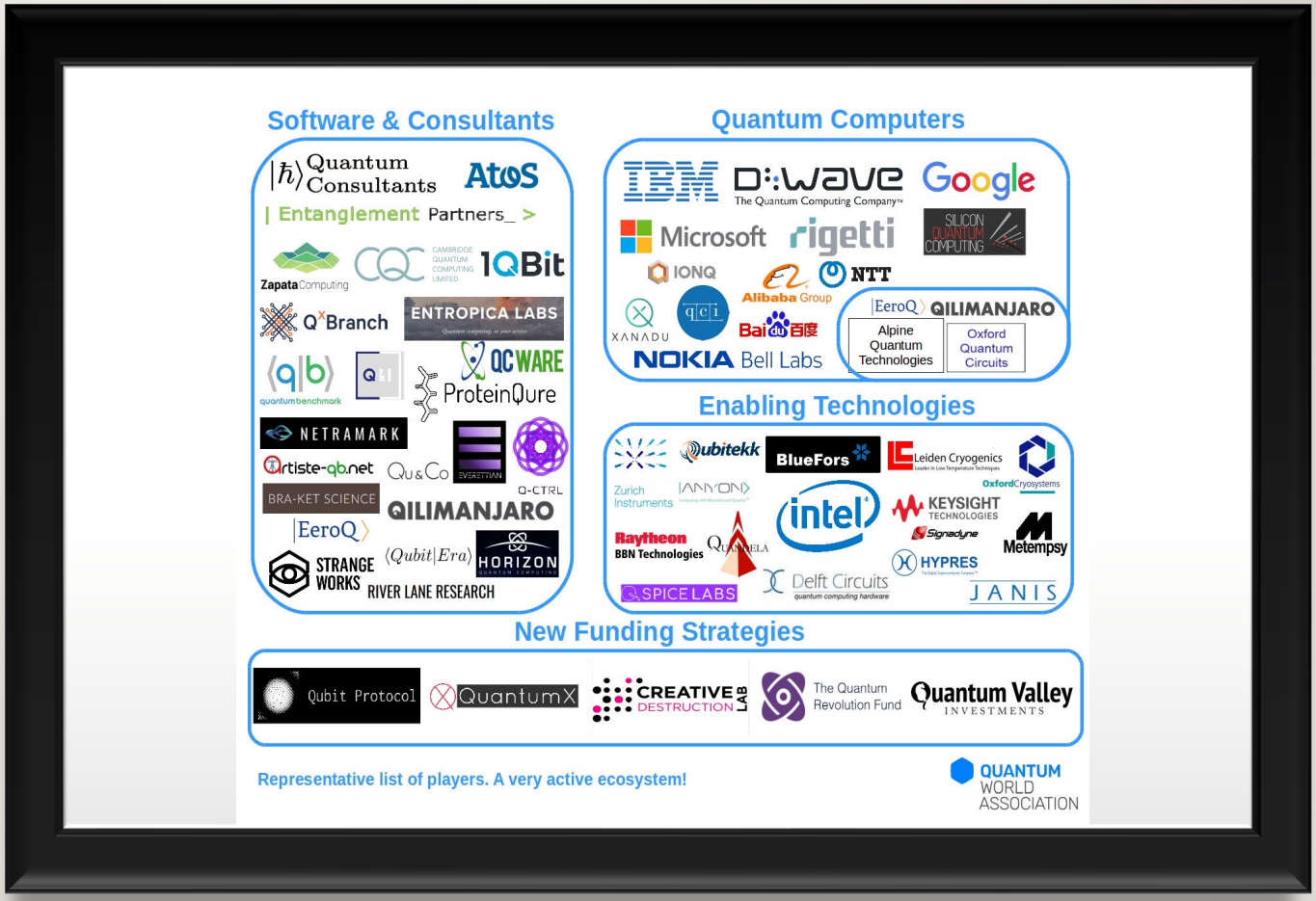


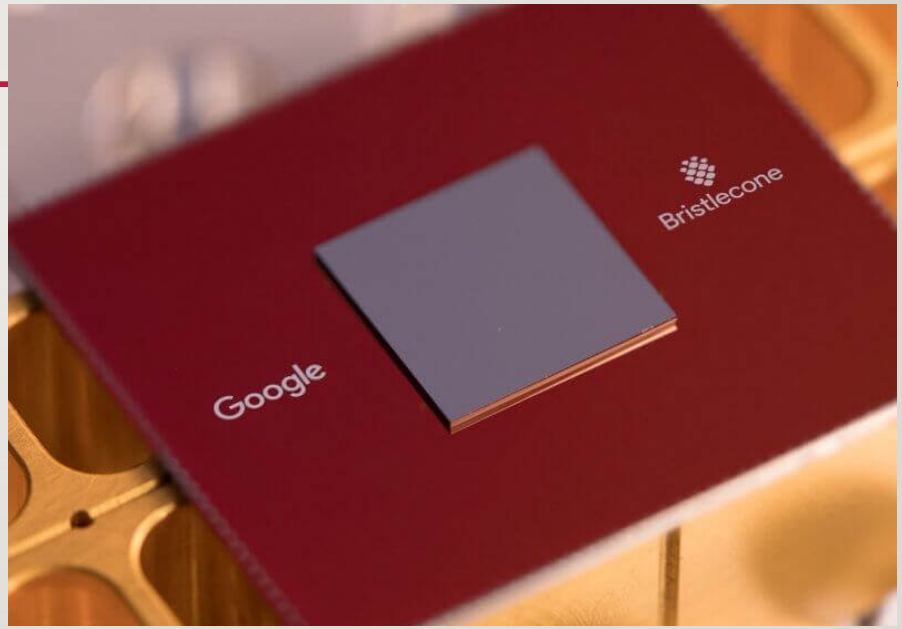
SAMPLE QUANTUM COMPUTERS

QUANTUM COMPUTING PLAYERS



GOOGLE BRISTLECONE

- 72 qubit quantum computer in a chip.
- Mainly used for research and innovations
- For creating algorithm building



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GOOGLE SYCAMORE CHIPS

2^{52}

Times of processing.

Google showcased the

Quantum Supremesy???

- New computational capability that is not feasible by typical super computers of the world.

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IBM QUANTUM COMPUTING PROGRESS

June-2022 release by IBM

1386-qubit processor – Kookaburra

4,158-qubit POC system built using three connected Kookaburra processors by 2025

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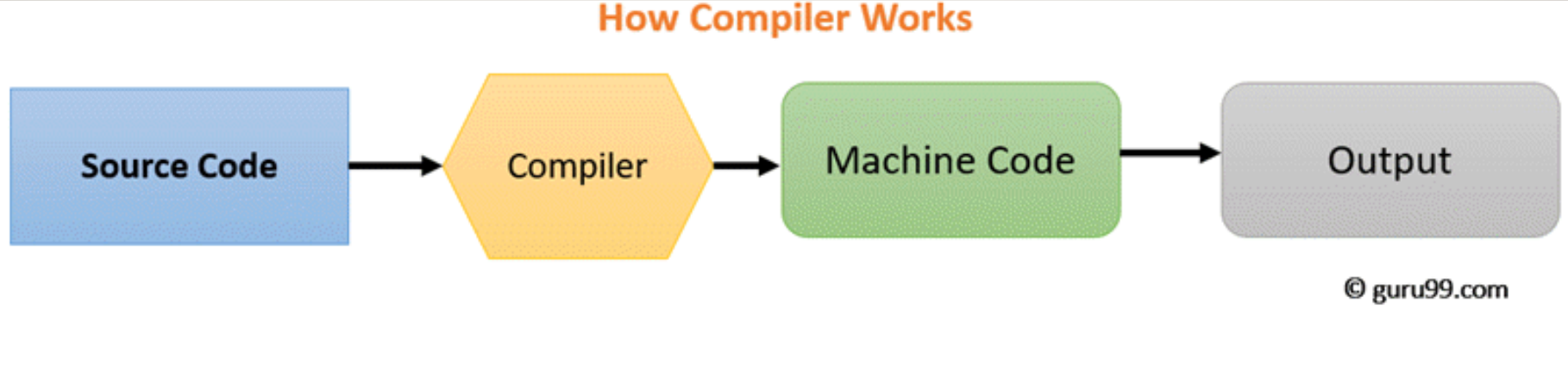
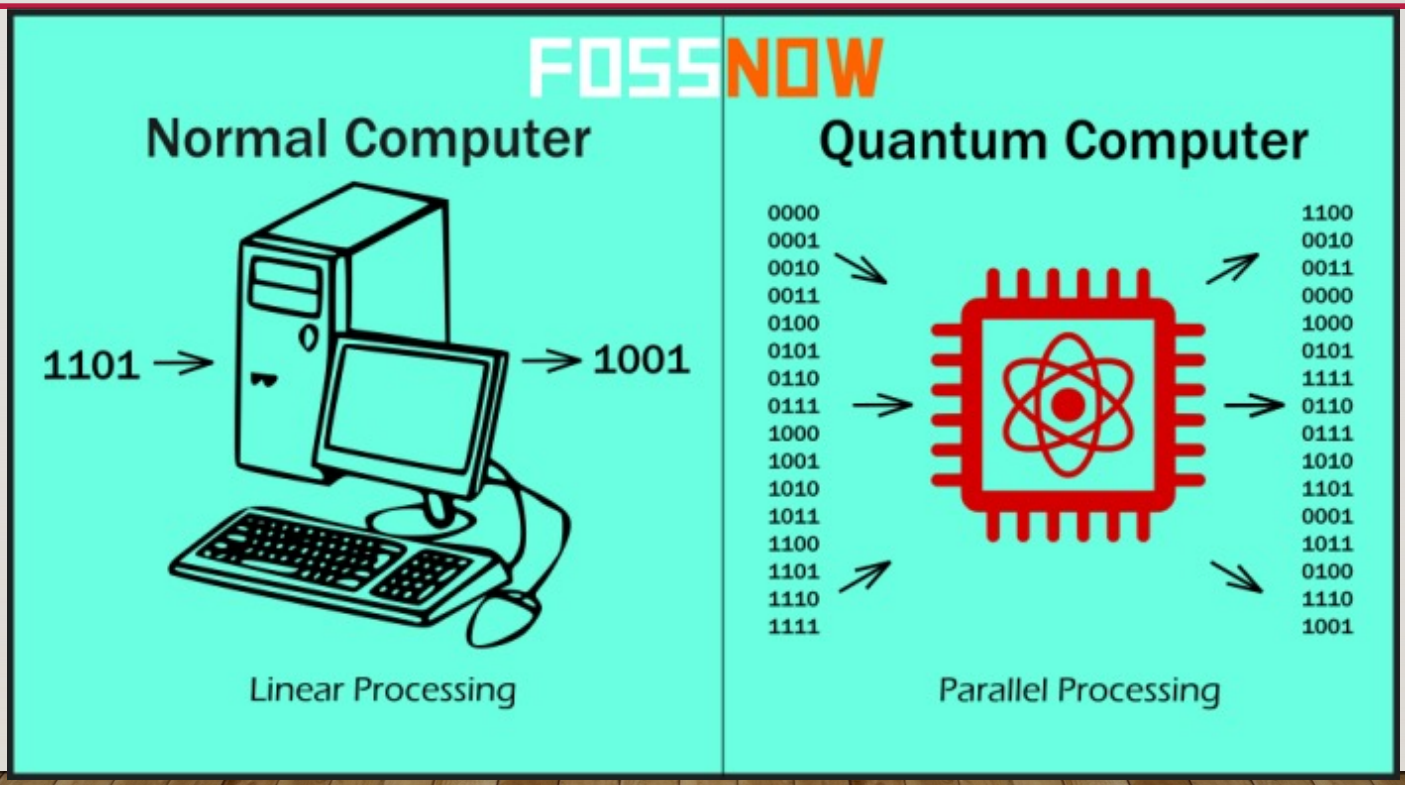
CLASSICAL COMPUTER EXECUTION METHOD



QUANTUM COMPUTER



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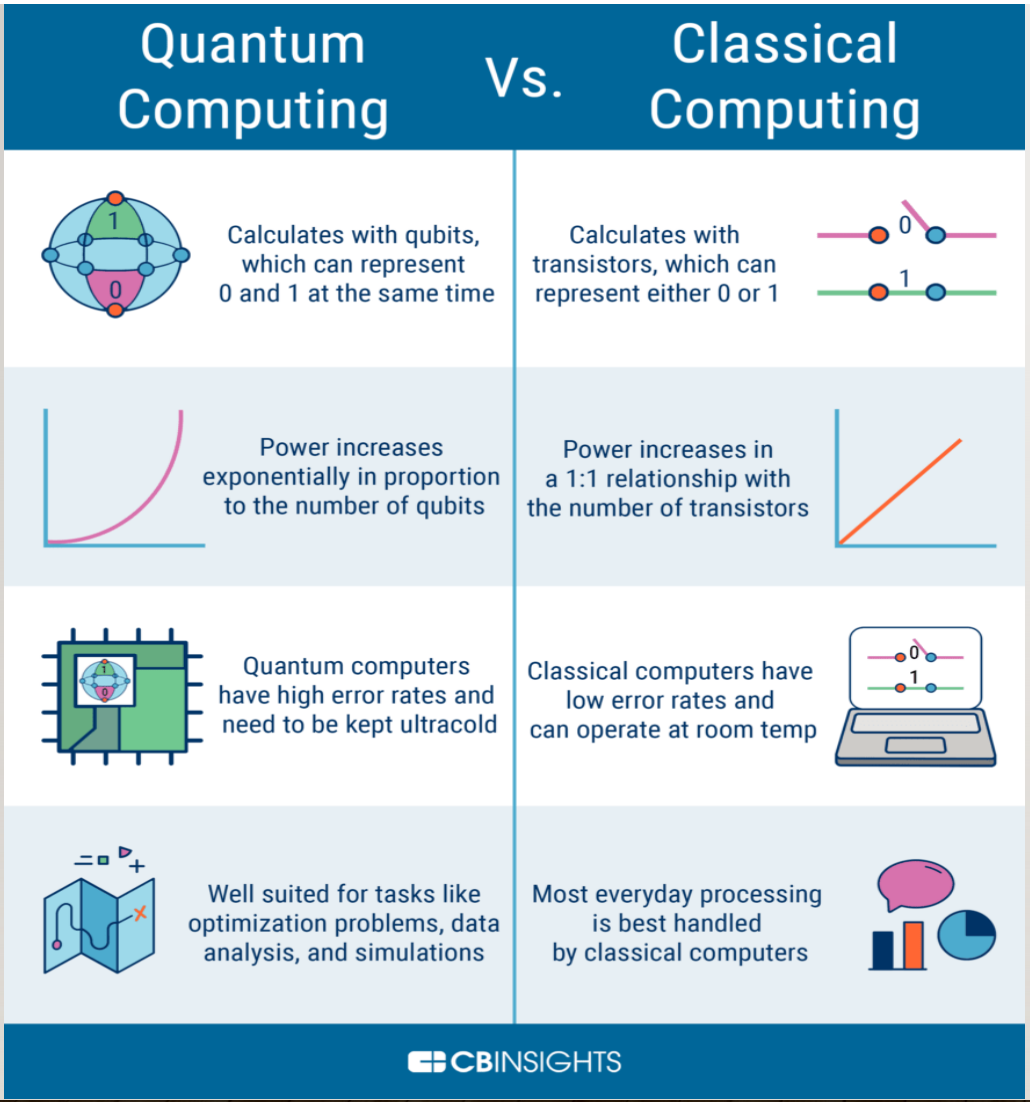
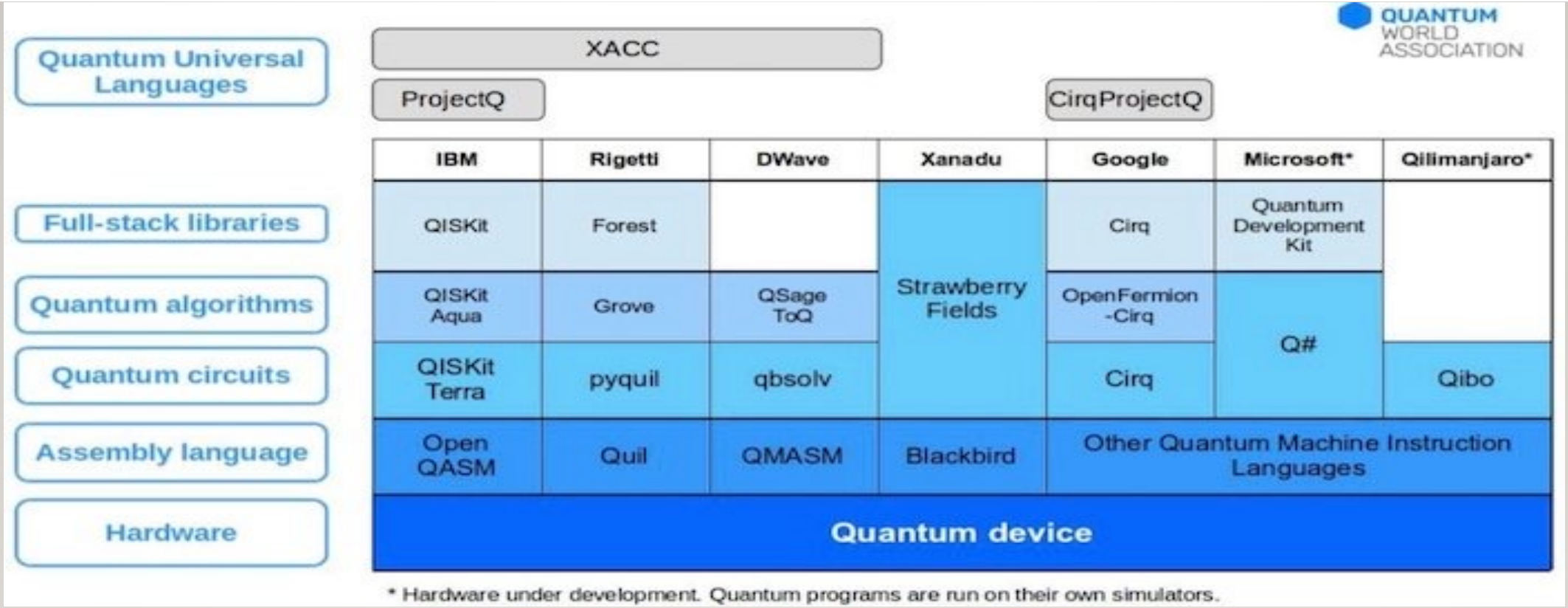
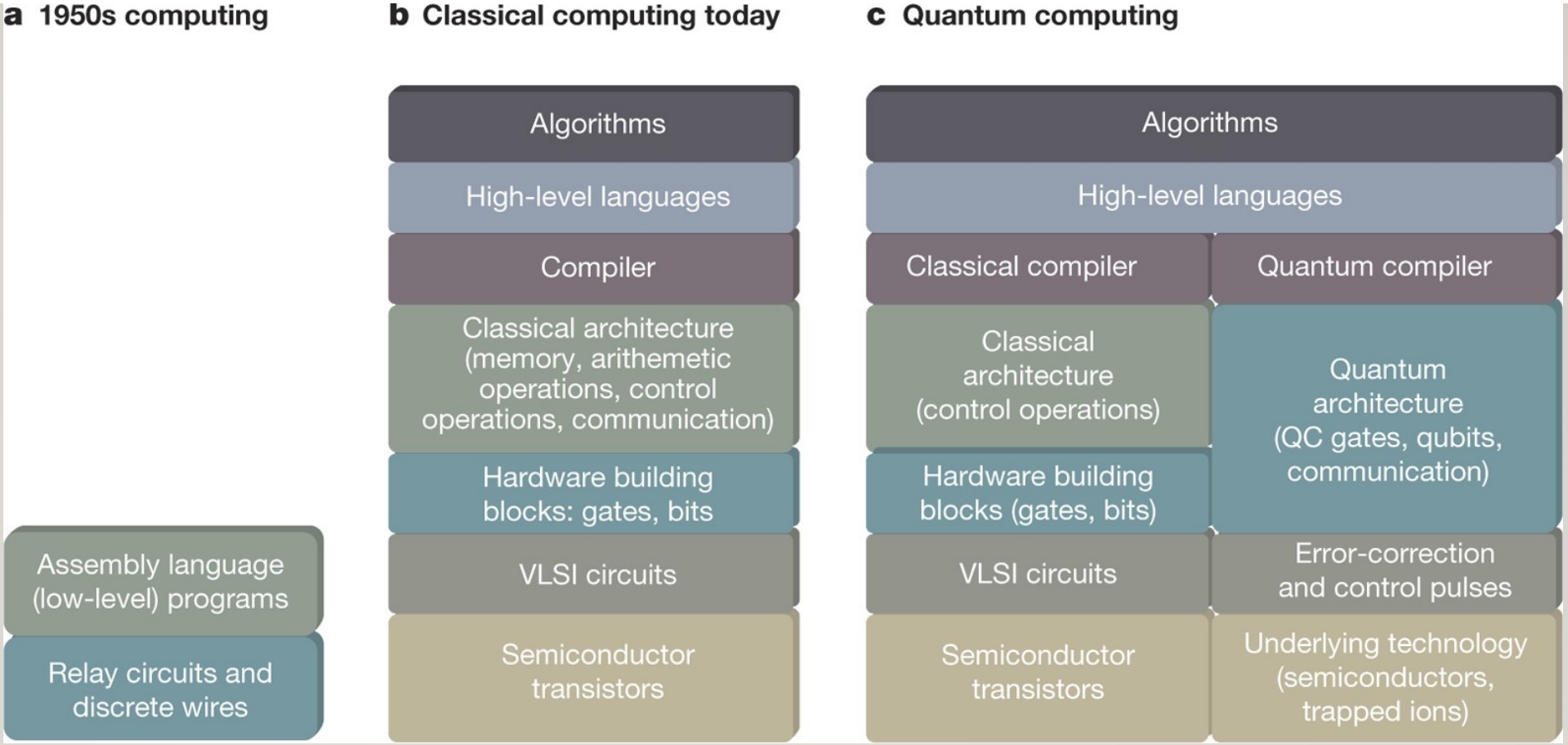
COMPARING QUANTUM AND CLASSICAL COMPUTING

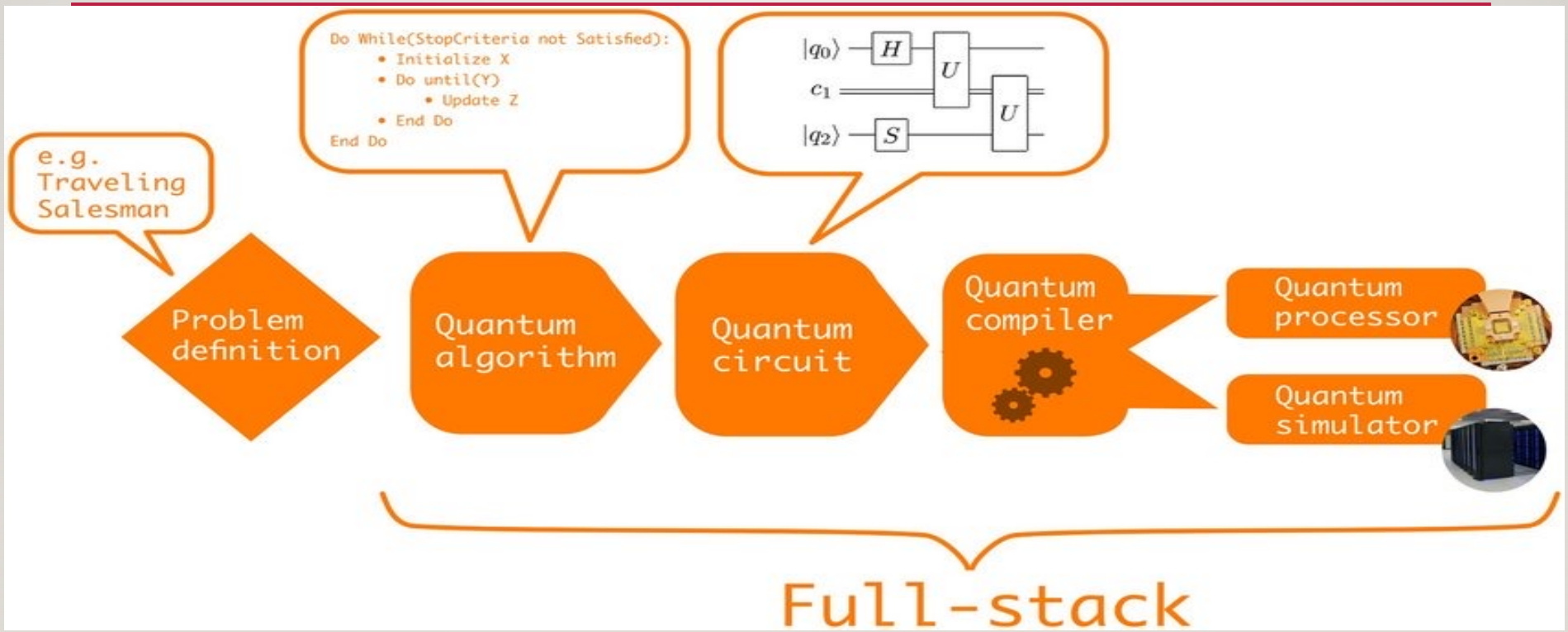




VARIOUS QUANTUM PROGRAMMING FRAMEWORKS

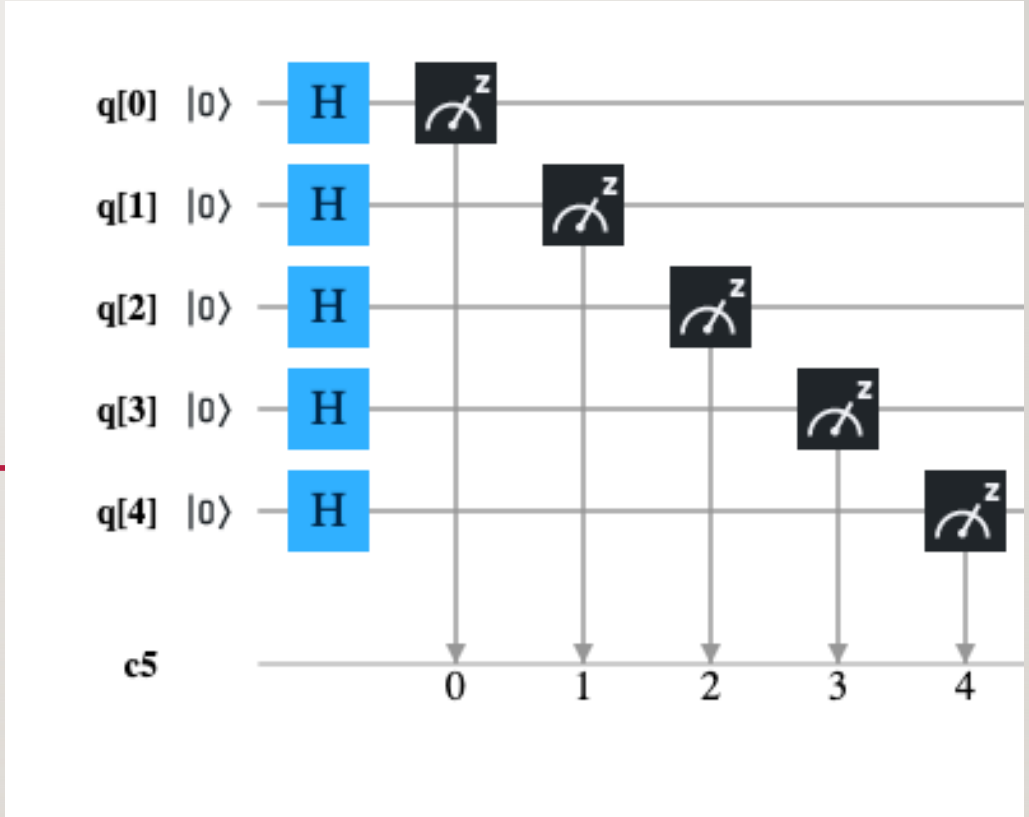

a 1950s computing
Assembly language (low-level) programs
Relay circuits and discrete wires
b Classical computing today
Algorithms
High-level languages
Compiler
Classical architecture (memory, arithemetic operations, control operations, communication)
Hardware building blocks: gates, bits
VLSI circuits
Semiconductor transistors
c Quantum computing
Algorithms
High-level languages
Classical compiler
Quantum compiler
Classical architecture (control operations)
Quantum architecture (QC gates, qubits, communication)
Hardware building blocks (gates, bits)
VLSI circuits
Error-correction and control pulses
Semiconductor transistors
Underlying technology (semiconductors, trapped ions)

QUANTUM PROGRAMMING FLOW

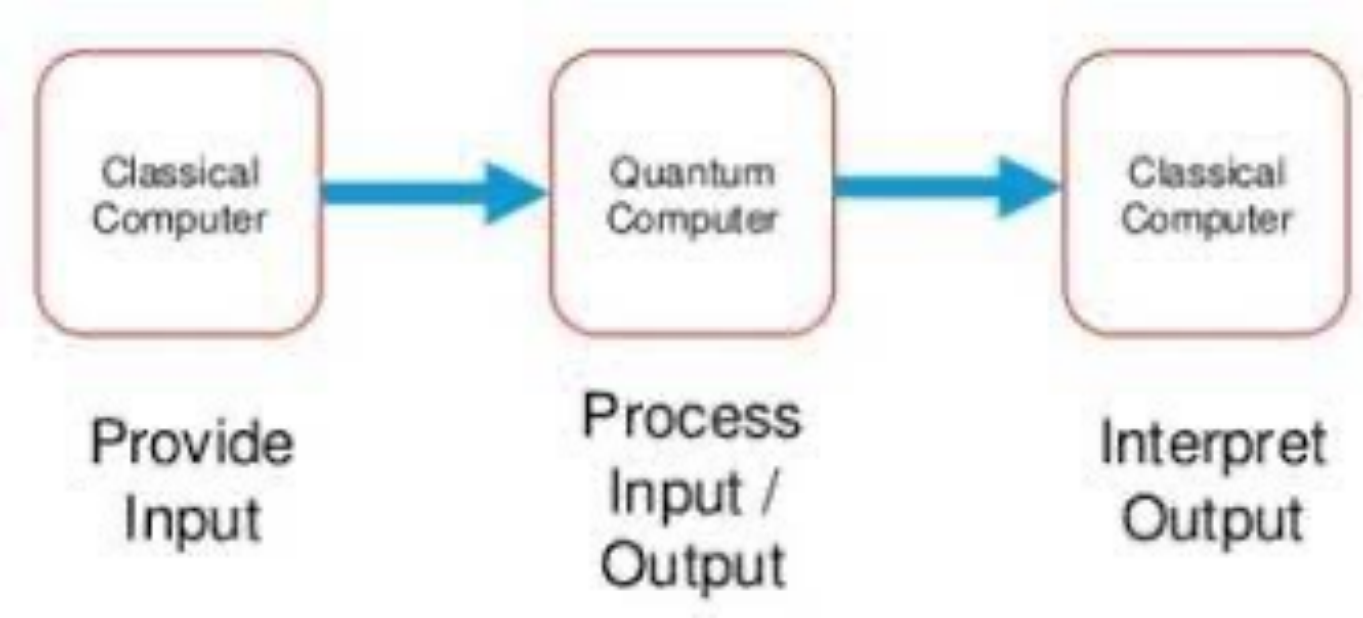


QUANTUM CIRCUIT – EXAMPLE

RANDOM NUMBER GENERATION ALGO



INTERACTING WITH QUANTUM COMPUTER



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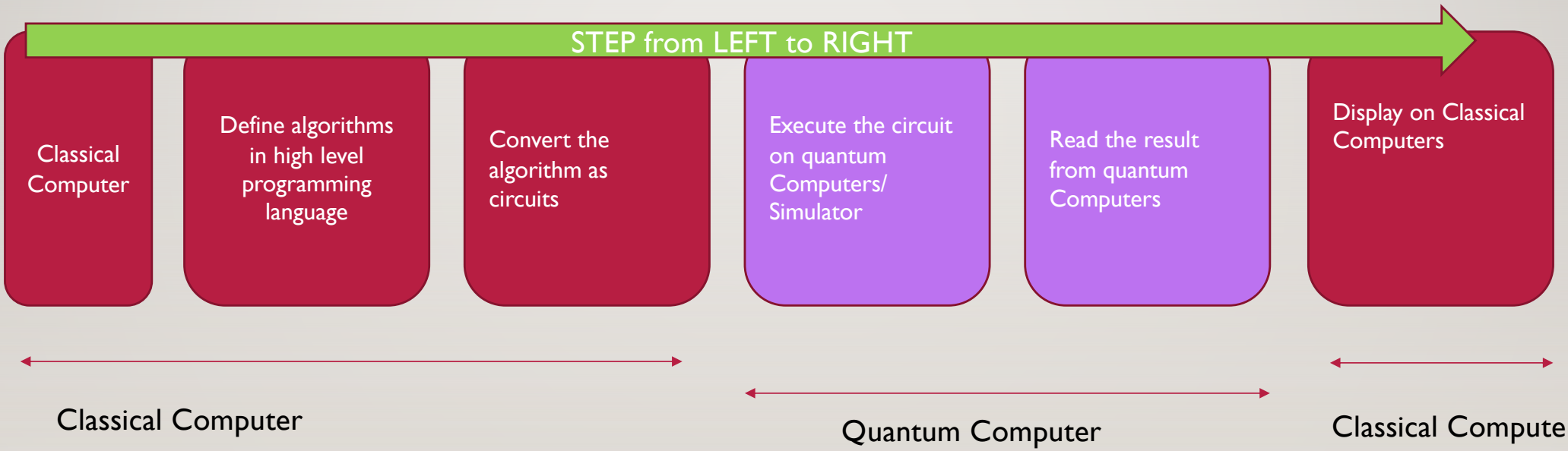
CLASSIAL COMPUTER TO QUANTUM COMPUTER INTERACTION



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GOOGLE CIRQ – INTRODUCTION

- Open Source Programming language for Quantum Algoritms and Circuit Building.
- Available on GitHub - https://quantumai.google/cirq $ https://github.com/quantumlib/cirq
- Python library for writing, manipulating, and optimizing quantum circuits and running them against quantum computers and simulators.
- Enable users to create Qubits, Gates, Operations, Circuits, Moments, Apply simulation or real device execution and visualize the result.

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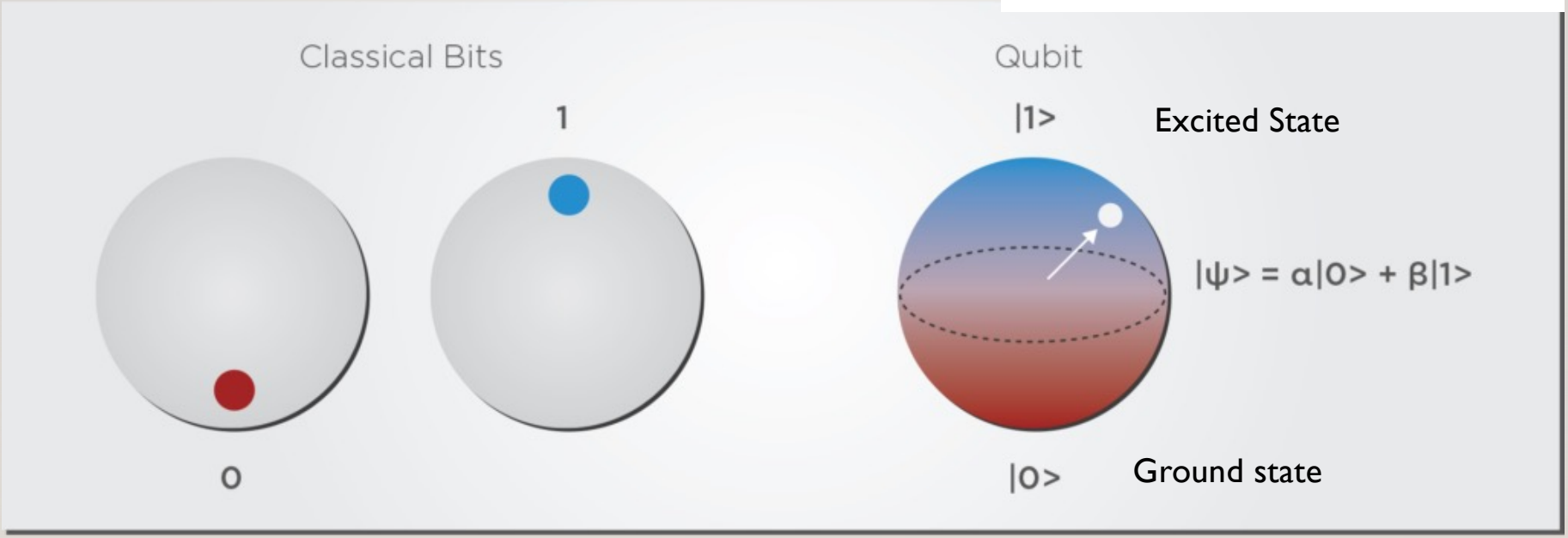
QUBIT INTRO

$$|0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \quad |1\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

|0> = Ket Notation to represent the Qubit.



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QUANTUM QUBIT IN BLOCH SPHERE

State of the qubit | Probability of the **0** state | Probability of the **1** state

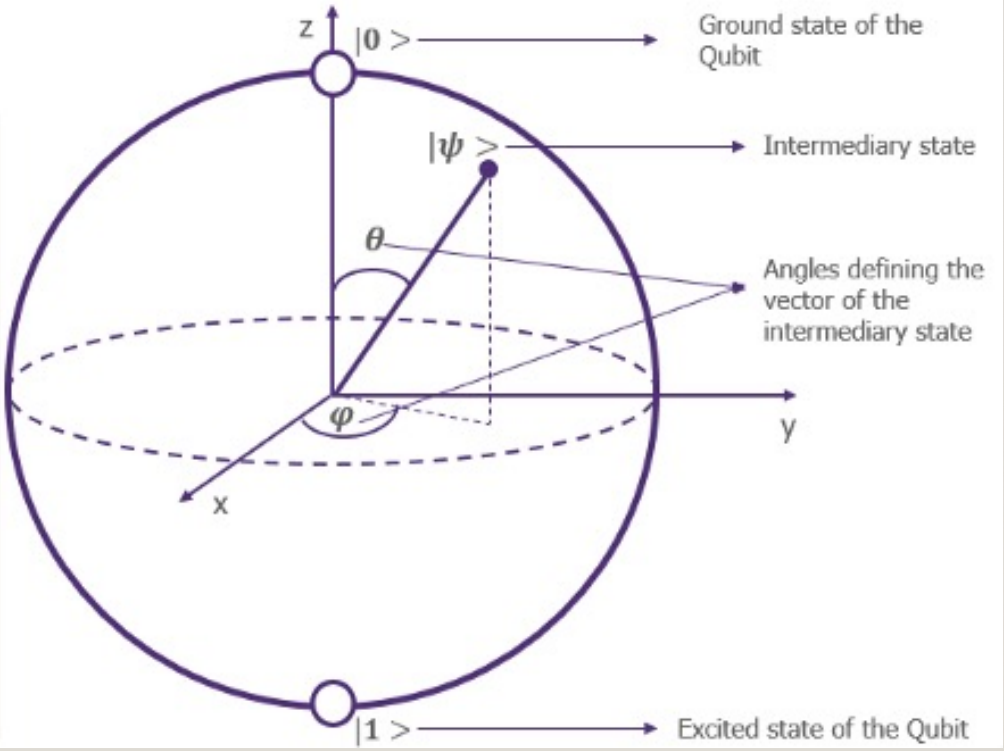
$$|\psi> = \alpha\,|0> + \beta\,|1>$$

$$|\alpha|^2 + |\beta|^2 = 1$$

The relationship between α and β according to the **Max Born** rule, related to the **Schrodinger** wave function that defines the states |0> and |1>

$$|\psi> = \begin{bmatrix} \alpha \\ \beta \end{bmatrix} \begin{matrix} \longrightarrow \cos(\frac{\theta}{2}) \\ \longrightarrow \exp(i\varphi)\sin(\frac{\theta}{2}) \end{matrix}$$

Euler formula



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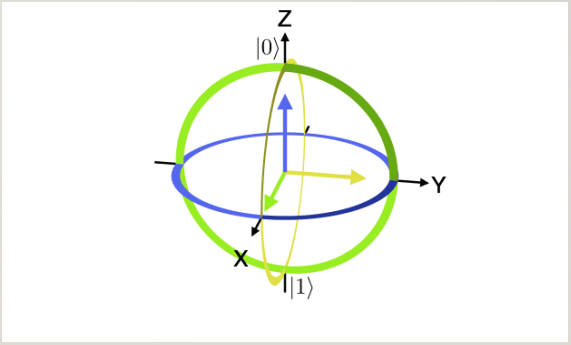
BASICS OF QUANTUM COMPUTING

- State Vector Representation of Qubit
  - state of a physical system in quantum mechanics is represented by **a vector belonging to a complex vector space**. This vector is known as the state space of the system.
  - Such a physical state of a **quantum system** is represented by a symbol | ⟩, known as a **ket**.

$$|0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix} |1\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$



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BASICS OF QUANTUM COMPUTING

- **Quantum Entanglement**
  - If two qubits are in quantum entanglement then if one qubit value is observed other qubit value is automatically identified.
  - i.e you have two gloves in a box
    - If you take out left hand glovse
    - You are sure and know that the other gloves is right hand one!
  - CNOT Gate is used for quantum entanglement

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PRACTICAL-1

- Please open the file - **Quantum ML Workshop - Intro to Cirq - 1.ipynb** in Google COLAB.

- Download the above file from Github Link: https://github.com/prasannavj/QuantumMachineLearning
- Google COLAB:
  - Search for Google COLAB
  - Click on the result
  - File -> Upload Notebook

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REPRESENTING QUBIT IN CIRQ

- 3 type of Qubits
  - Named Qubit
    - cirq.NamedQubit('target')
  - Line Qubit
    - cirq.LineQubit.range(2)
  - Grid Qubit
    - cirq.GridQubit(4, 5)

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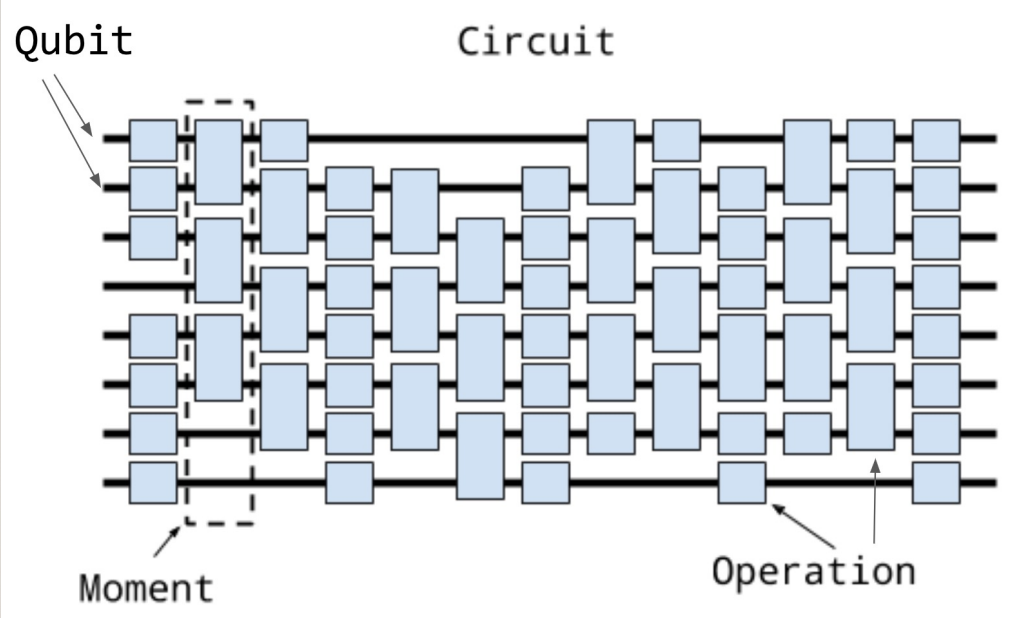
QUBITS, OPERATIONS, MOMENTS AND CIRCUITS



•A **Circuit** is a collection of **Moments**.

•A **Moment** is a collection of **Operations** that all act during the same abstract time slice.

•An **Operation** is an effect that operates on a specific subset of **Qubits**.

- The most common type of Operation is a Gate applied to several qubits (a "GateOperation").

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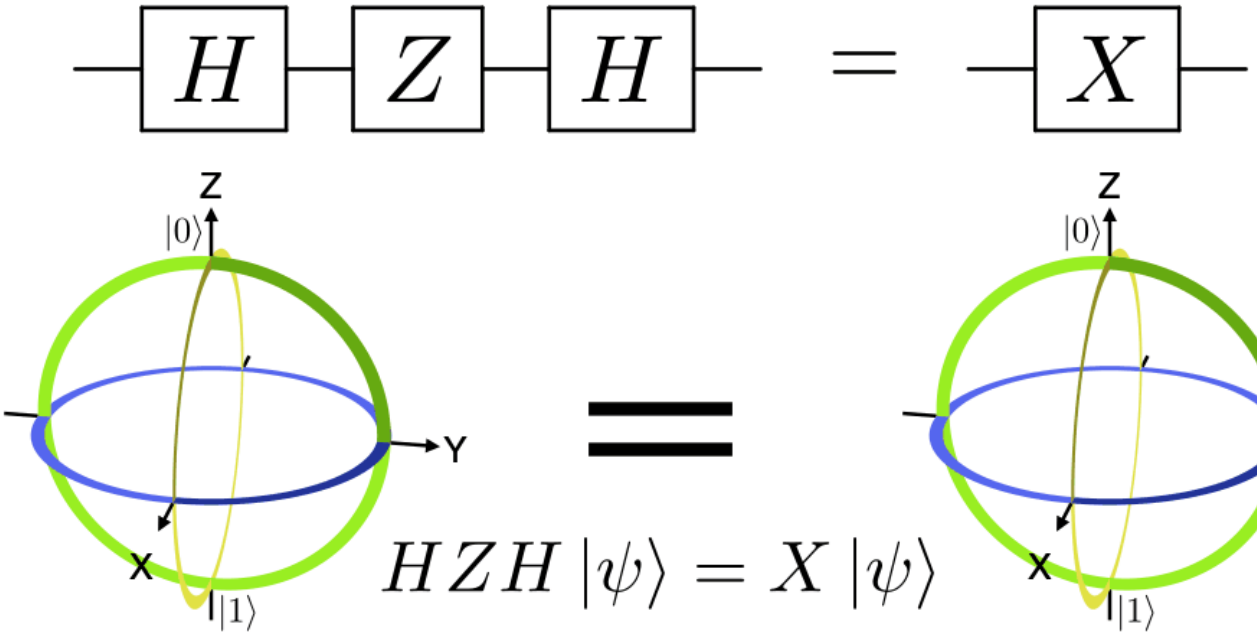
SAMPLE CIRCUIT FLOW



$$HZH\,|\psi\rangle = X\,|\psi\rangle$$

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GATES AND OPERATIONS

- Gates Introduction
  - CNOT gate – to Entangle two qubits.
    - cirq.CNOT
  - Hadamar Gate - Take the qubit to the superposition.
    - Cirq.H
  - X Gate – to rotate the X axis
    - Cirq.X
  - Y gate – to rotate on Y axis
    - Cirq.Y
  - Z Gate – to rorate on Z axis
    - Cirq.Z

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GATES AND OPERATIONS

- Operations
  - Square Root calculation
    - cirq.X**0.5
  - Perform Square calculation
    - cirq.YPowGate(exponent=0.25)

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CIRCUIT AND SIMULATION

- Create circuit
  - circuit = cirq.Circuit()
  - circuit.append()
- Simulating the result
  - cirq.Simulator()
  - simulator.run()

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ADVANCED SIMULATOR

- Qsim – Quantum simulator – dedicated advanced simulator python open source library for the simulation of the quantum computing
  - !pip install qsimcirq
  - qsimcirq.QSimSimulator()
  - qsim_simulator.simulate(circuit)

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PRACTICAL-2

- Please open the file - **Quantum ML Workshop - Advanced Cirq - 2.ipynb** in Google COLAB.

- Download the above file from Github Link: https://github.com/prasannavj/QuantumMachineLearning
- Google COLAB:
  - Search for Google COLAB
  - Click on the result
  - File -> Upload Notebook

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ADAVCNED CIRCUITS AND OPERATIONS

- Creating custom gates
  - Python class inhert the details from cirq.Gate
    - Define Number of Qubit details.
    - Define Unitay Matrix detils
    - Define Circuit diagram information

- Importing and exporting the circuits
  - cirq.to_json
  - cirq.read_json

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INTERACTING WITH THE QUANTUM DEVICE

- Importing device access details
  - cirq_google.Sycamore – to get the Sycamore device for our execution.
  - cirq_google.Sycamore.metadata.gate_durations – to get duration of an operations
  - cirq_google.Sycamore.validate_operation
    - Quantum devices has many device restrictions and the validate_operation used to validate whether these operations are valid or not before executing.
    - One of the basic validation is Operation on non-adjacent qubits will raise an error.

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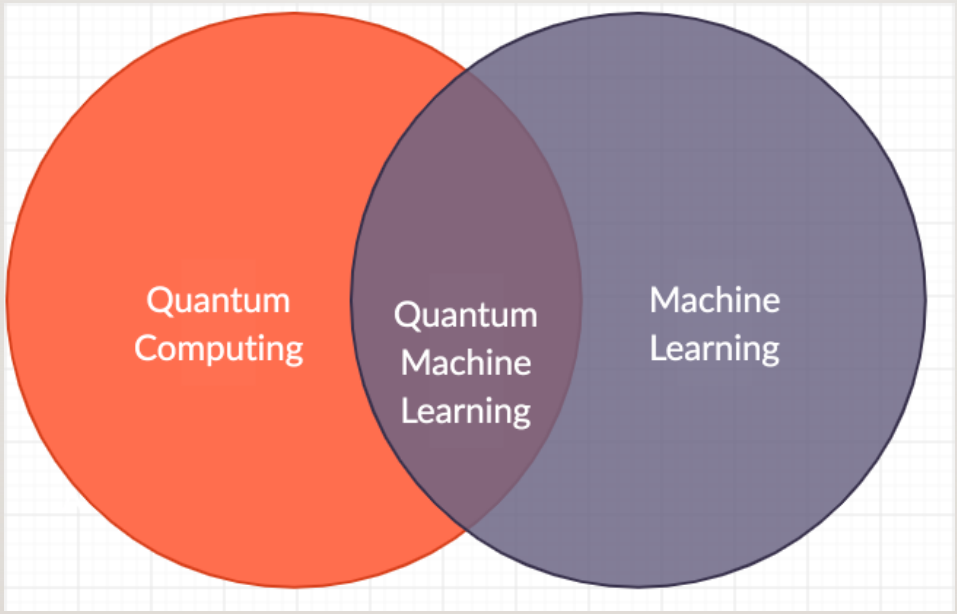
QUANTUM MACHINE LEARNING



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GOOGLE TENSORFLOW QUANTUM

- Quantum machine learning library from google
- Open source library
- Released in 2020
- In colloboration with univ of waterloo and Voswagon team
- TensorflowQuantum(TFQ)
- Underthehood "Cirq" integrate "Tensorflow"

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UNDERSTAND TENSORFLOW QUANTUM(TFQ)

- Quantum Data
  - *Quantum data* exhibits superposition and entanglement, leading to joint probability distributions that could require an exponential amount of classical computational resources to represent or store.
- Hybrid Quantum classical models
  - Tensorflow extended to support the quantum hybrid quantum classical algorithms

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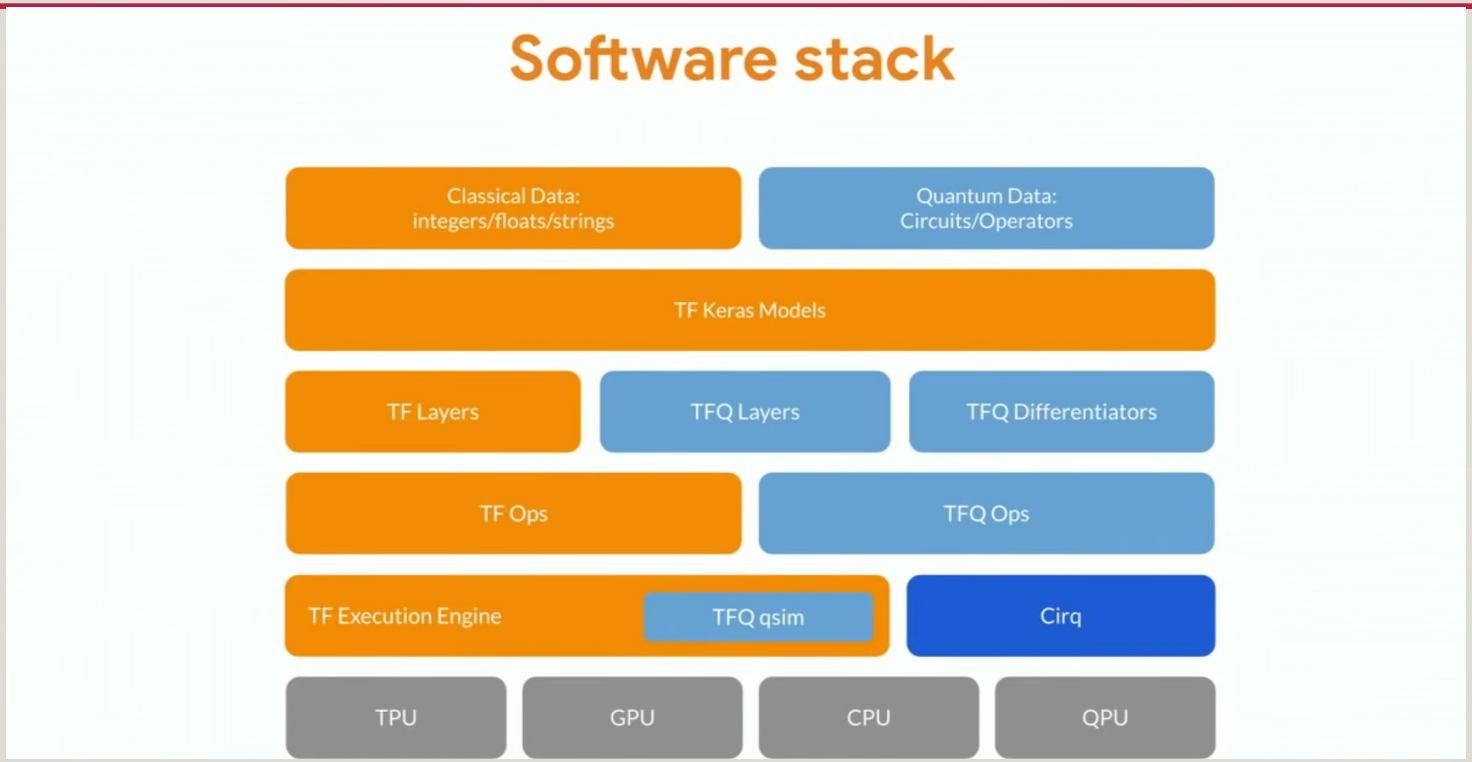
TENSORFLOW QUANTUM



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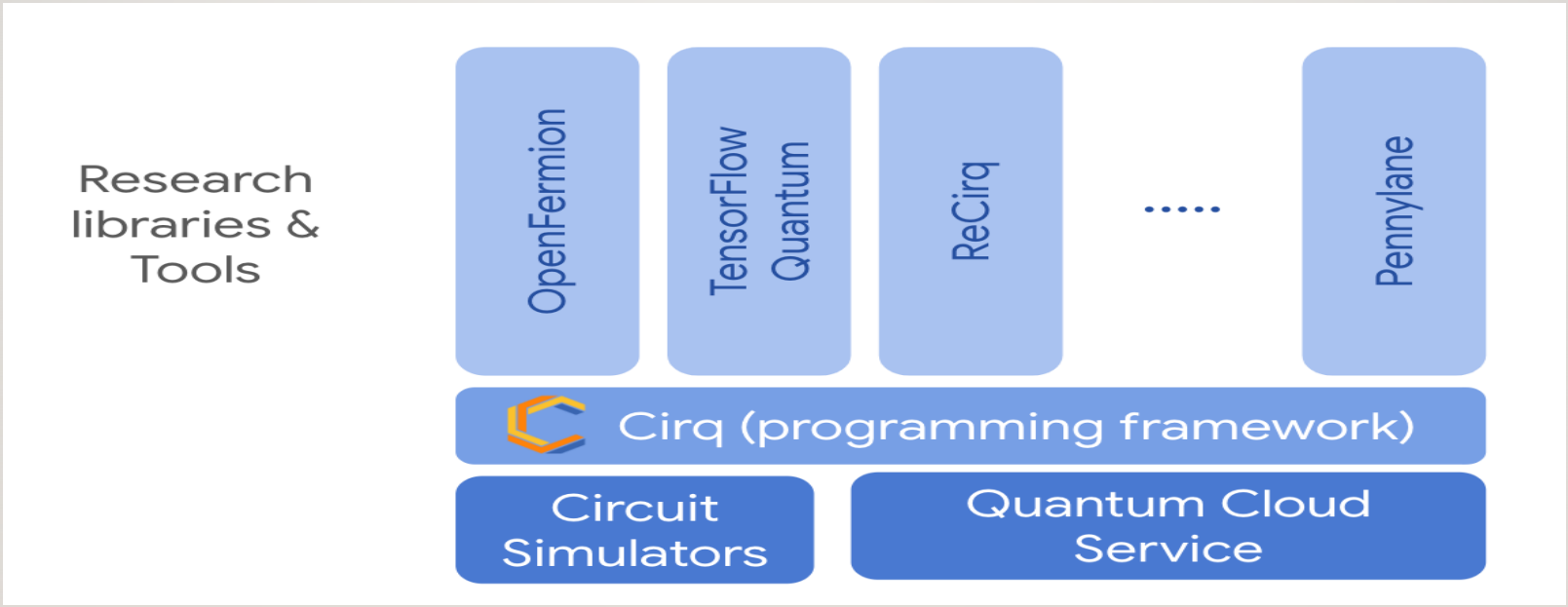
TENSORFLOW QUANTUM



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SUPPORTED QUANTUM CLOUD SERVICES

Company	Type of Quantum Computer
Alpine Quantum Technologies	Trapped ions
IonQ	Trapped ions
Microsoft Azure Quantum	**Trapped ions (Honeywell and IonQ)**
Pasqal	Neutral atoms
Rigetti	Superconducting qubits

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TENSORFLOW QUANTUM – DESIGN PRINCIPLES

1. **Differentiability:** Must support differentiation of quantum circuits and hybrid backpropagation.
2. **Circuit Batching:** Quantum data loaded as quantum circuits, training over many different quantum circuits in parallel.
3. **Execution Backend Agnostic**: Switch from a simulator to a real device easily with few changes.
4. **Minimalism:** A bridge between Cirq and TF; does not require users to re-learn how interface with quantum computers or solve problems using machine learning.

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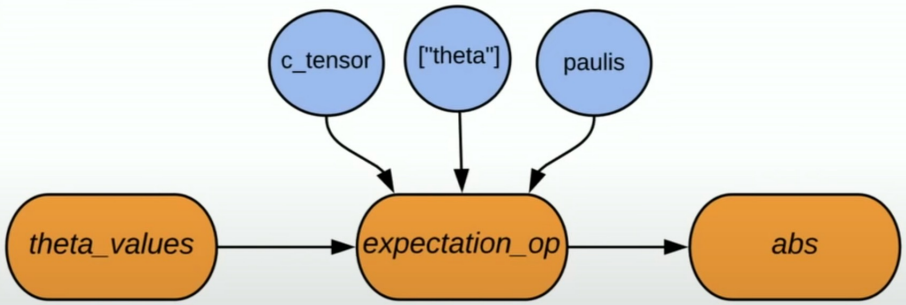
TENSORFLOW QUANTUM

Software architecture

- Circuits are **TENSORS**, use Cirq constructs to generate these tensors
- Converting circuits to classical data (aka running or simulating them) can be done by **OPs**



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PRACTICAL-3

- Please open the file - **Quantum ML Workshop - Quantum Machine Learning Basics - 3.ipynb** in Google COLAB.

- Download the above file from Github Link: https://github.com/prasannavj/QuantumMachineLearning
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  - Search for Google COLAB
  - Click on the result
  - File -> Upload Notebook

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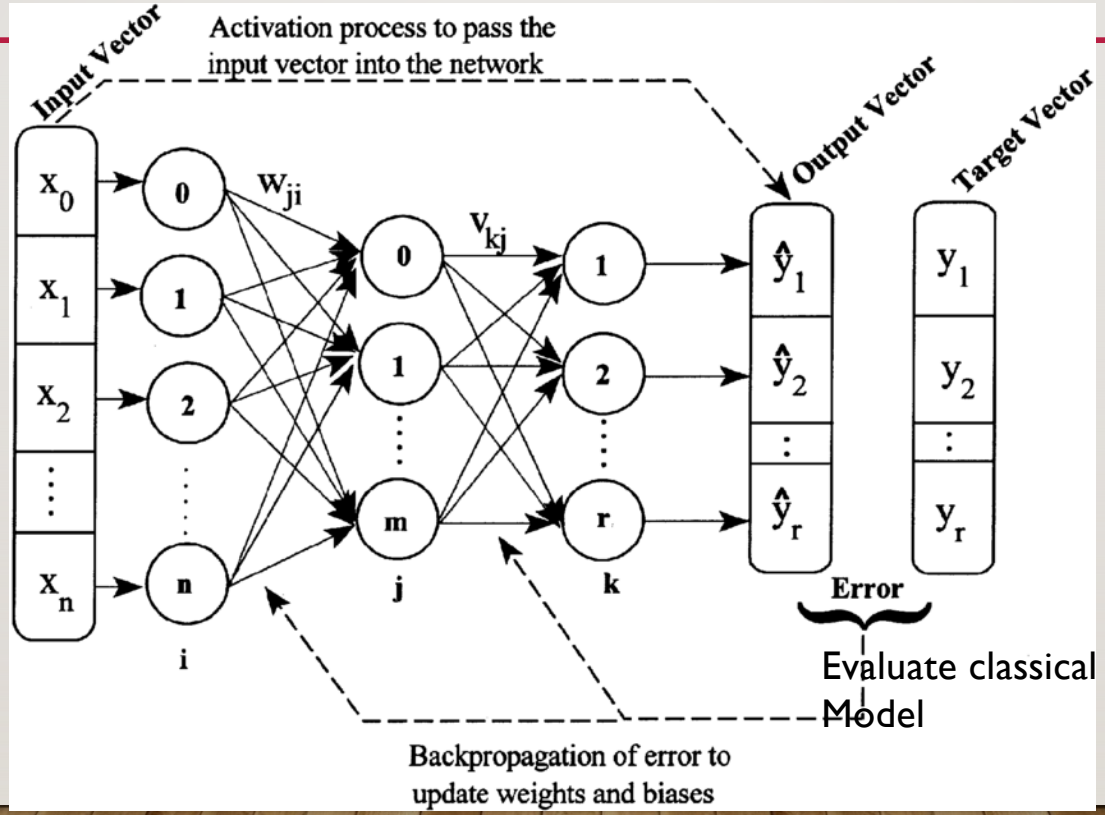
TYPICAL NEURAL NETWORK

Prepare Data



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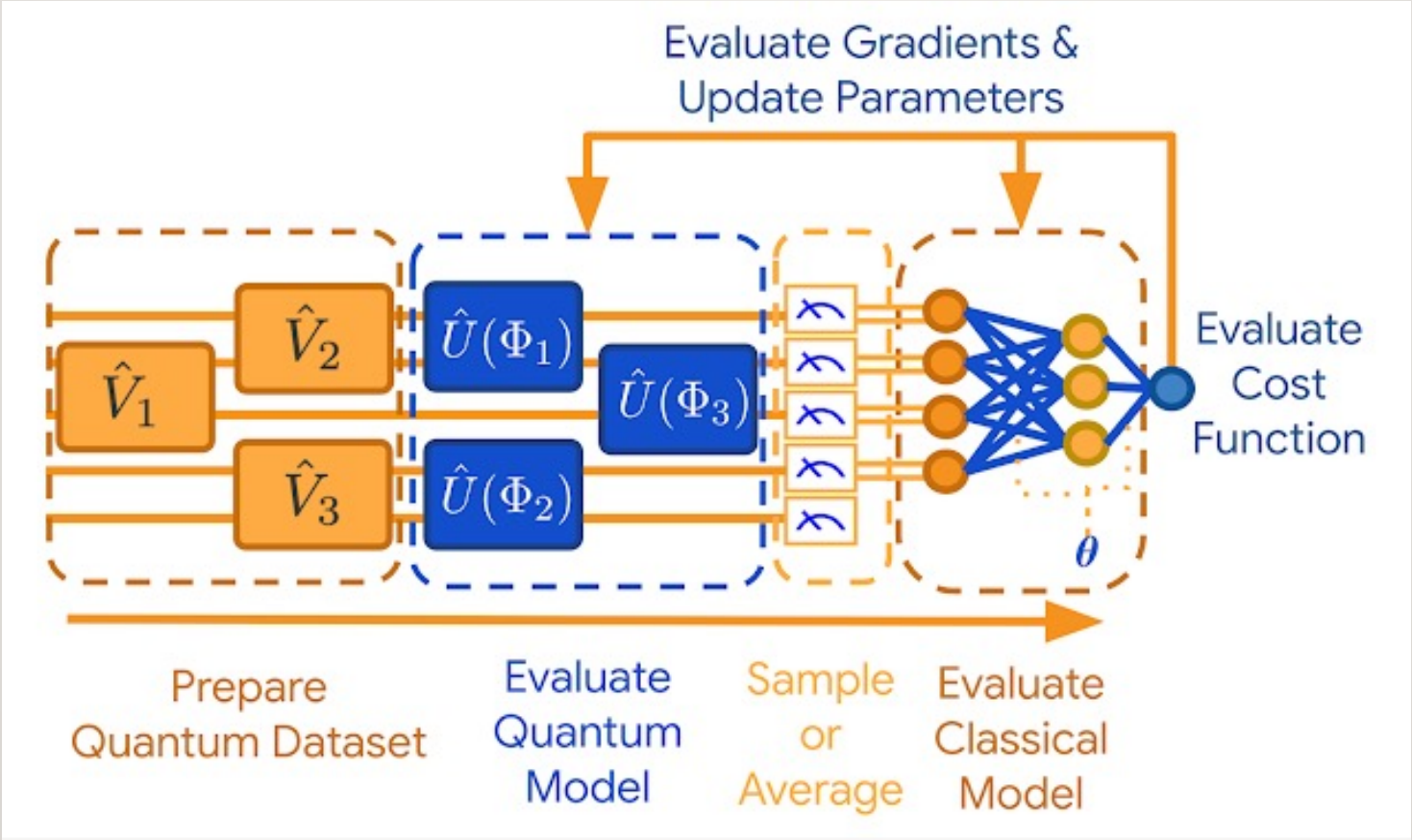
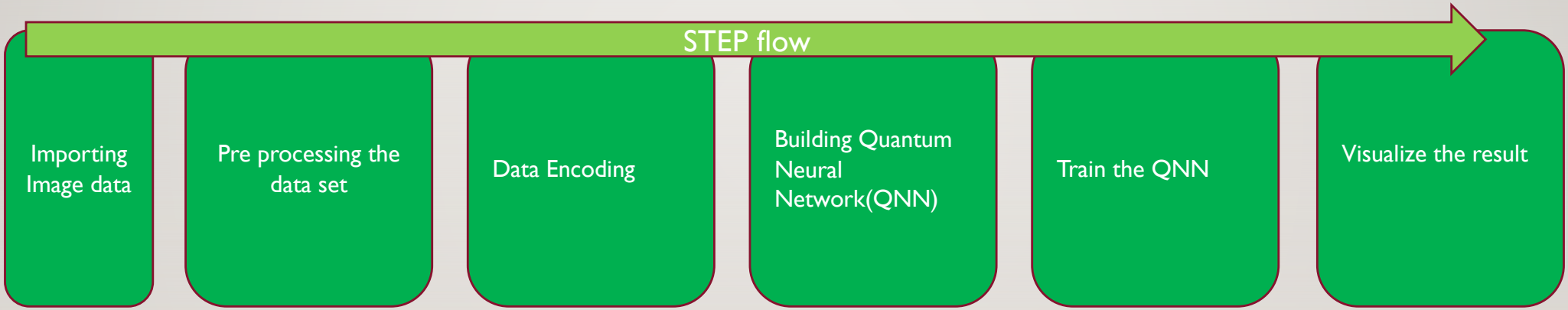
USING TENSORFLOW QUANTUM



HYBRID QUANTUM MACHINE LEARNING APPROACH

- Image Classification on Fashion MNIST with TensorFlow-Quantum and Cirq



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SYMPY AND CIRQ

- SYMPY – Symbolic parameters to the cirquit can be added using the SYMPY library
- SVGCircuit - for better visual representation of the Circuits (A Custom Circuit Visualizer)
- QNN – Quantum Neural Network
- Cirq.xx – tensor product of two x gate
- Cirq.yy – tensor product of two y gate

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PRACTICALS - 4

- Please Download the file from GitHub Repo:
  - https://github.com/prasannavj/QuantumMachineLearning
- Quantum ML Workshop - Quantum Machine Learning Advanced - 4 - Image_Classification_on_Fashion_MNIST_with_TensorFlow_Quantum_and_Cirq.ipynb

GOOGLE QUANTUM SUMMER SYMPOSIUM

- 19-22-Jul – Register for Free –

- https://eventsonair.withgoogle.com/events/qss-2022

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