Part 2

Classic Physics

Newton's Laws of Motion:

a) Newton's First Law (Law of Inertia): An object at rest tends to stay at rest, and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an external force.

b) Newton's Second Law of Motion: The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. It can be mathematically expressed as $F = ma$, where F is the force, m is the mass, and a is the acceleration.

c) Newton's Third Law of Motion: For every action, there is an equal and opposite reaction.

Law of Universal Gravitation (Newton):

- Every particle attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.
- The formula is F = G * (m1 * m2) / r^2, where F is the gravitational force, G is the gravitational constant, m1 and m2 are the masses of the two objects, and r is the distance between them.

Hooke's Law:

- The force exerted by a spring is directly proportional to the displacement or extension of the spring from its equilibrium position. It can be expressed as F = k * x, where F is the force, k is the spring constant, and x is the displacement.

- **Law of Conservation of Energy:**
- Energy cannot be created or destroyed but can only be transferred or transformed from one form to another. The total energy of a closed system remains constant.

Ohm's Law:

- The current flowing through a conductor is directly proportional to the voltage across it and inversely proportional to its resistance. Mathematically, it is expressed as V = IR, where V is the voltage, I is the current, and R is the resistance.

Coulomb's Law:

- The electrostatic force between two charged particles is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.
- It can be written as F = k * (q1 * q2) / r^2, where F is the electrostatic force, k is the electrostatic constant, q1 and q2 are the magnitudes of the charges, and r is the distance between them.

Equation summary: linear motion

- $v = d/t$

v=speed (or velocity)
d=distance
t=time

- $p = mv$

p=momentum
m=mass

- $a = v/t$

a=acceleration

- $F = ma$

F=Force

What is Quantum Physics ?

- Quantum physics is **the study of matter and energy at the most fundamental level**.
- It aims to uncover the properties and behaviors of the very building blocks of nature.
- While many quantum experiments examine very small objects, such as electrons and photons, quantum phenomena are all around us, acting on every scale.

What is the main theory of quantum physics?

- It holds that as soon as a potential exists for any object to be in any state, the universe of that object transmutes into a series of parallel universes equal to the number of possible states in which that the object can exist, with each universe containing a unique single possible state of that object.

How is quantum physics different from physics?

- In classical physics, the outcomes of measurements can be **predicted** perfectly, assuming full knowledge of the system beforehand. **In quantum mechanics, even if you have full knowledge of a system, the outcomes of certain measurements will be impossible to predict**.

- **Quantum mechanics** is **the branch of physics that deals with the behavior of matter and light on a subatomic and atomic level**.
- It attempts to explain the properties of atoms and molecules and their fundamental particles like protons, neutrons, electrons, and quarks.

- Many modern electronic devices are designed using quantum mechanics.
- Examples include **lasers, electron microscopes, magnetic resonance imaging (MRI) devices and the components used in computing hardware**.

- Quantum theory is **the theoretical basis of modern physics that explains the nature and behavior of matter and energy on the atomic and subatomic level**.
- The nature and behavior of matter and energy at that level is sometimes referred to as quantum physics and quantum mechanics.

- **Quantum computing** is the area of study focused on developing computer technology based on the principles of quantum theory.
- The quantum computer, following the laws of **quantum physics**, would gain enormous processing power through the ability to be in **multiple states**, and to perform tasks using all possible permutations simultaneously.

How to learn quantum computing

- **Mathematics**. A detailed knowledge of advanced mathematics is incredibly useful in the field of quantum computing. Advanced algorithms are often at the heart of the field, as is a knowledge of areas such as *data analytics*.
- **Physics**. As we've discussed, quantum physics forms the foundation of quantum computing. Understanding the link between physics and technology can be hugely beneficial for those wishing to enter the field.
- **Programming**. Another key area is the ability to write and understand code. One of the key programming languages in quantum computing is *Python*, which forms the basis of the Qiskit software development kit often used in the industry.

QUANTUM COMPUTING MARKET MAP

Tractics

Quantum Encryption

Q→NU Proactively
EVERYWHERE IN YOUR LIFE
IDQ
Quintessence Labs
MagiQ.
TAQBit

Hardware

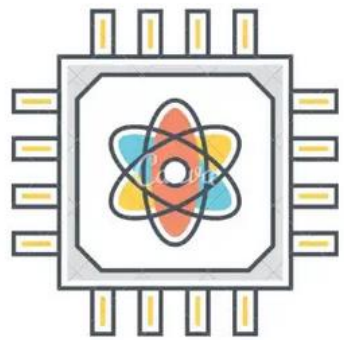
Optalysys
qutools
rigetti
AQT
TURING
IONQ
Quantum Circuits, Inc
D:wave The Quantum Computing Company

Software

quantum benchmark
STRANGE WORKS
1QBit
QBITLOGIC
QXBranch
QuSoft Research Center for Quantum Software
Q-CTRL
Artiste-qb.net

Building Quantum Computers

TURING
Quantum Circuits, Inc
Optalysys
IONQ
rigetti
D:wave The Quantum Computing Company
QILIMANJARO QUANTUM COMPUTING AT YOUR FINGERTIPS



Quantum AI

QBITLOGIC
CQC CAMBRIDGE QUANTUM COMPUTING
QINDOM
XANADU

Opticial Quantum Computers

PSIQ
QD LASER
QUANDELA
SINGLE QUANTUM Excellence in photon detection
Quantum Opus
SPARROW QUANTUM

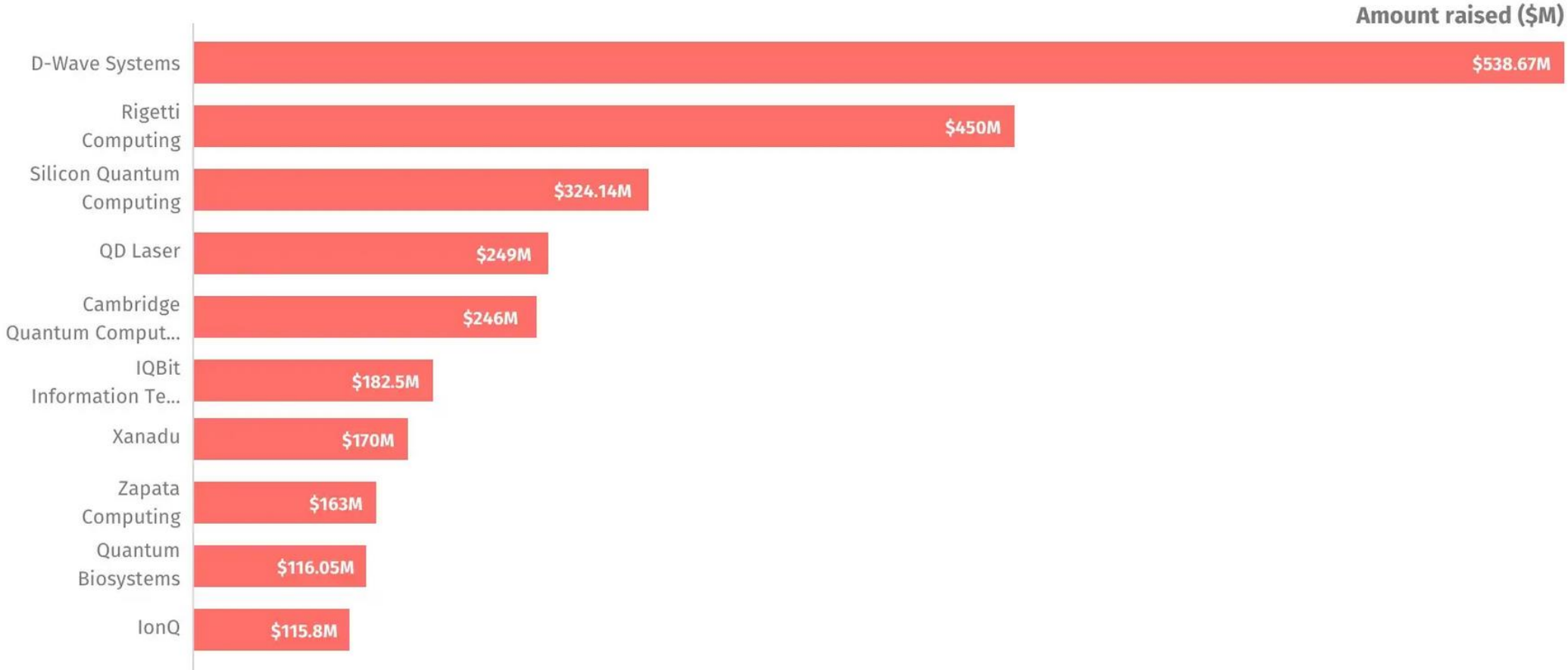
Quantum Cloud Computing

IONQ
Q-CTRL
rigetti
D:wave The Quantum Computing Company
QCWARE

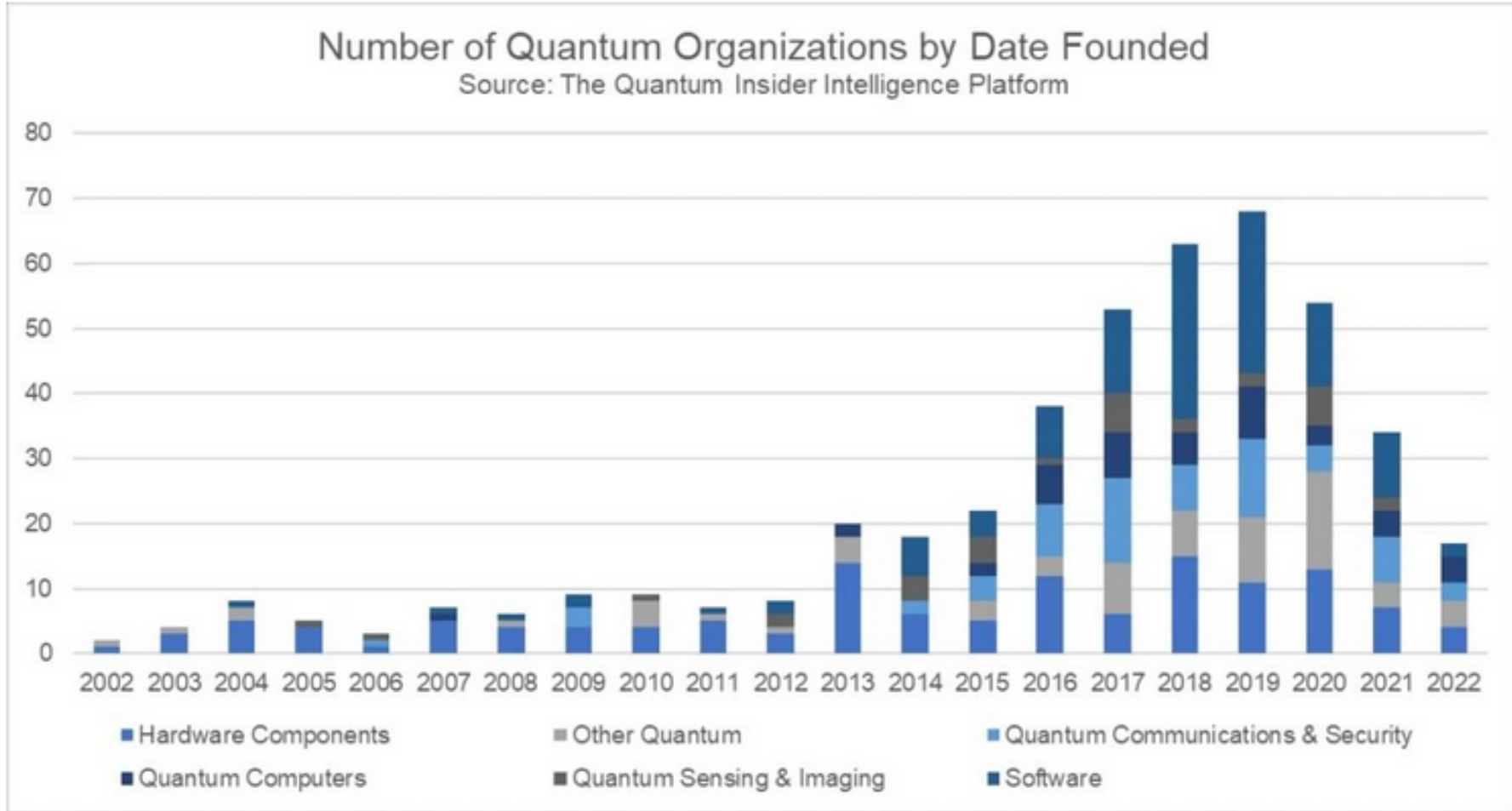
Quantum Circuits

BraneCell
QuTel, Inc
SILICON QUANTUM COMPUTING
Quantum Circuits, Inc

Top Funded Companies



The Rise of Quantum Computing Companies



Number of Quantum Organizations by date. Source: The Quantum Insider Intelligence Platform

Top Quantum Computing Companies

1. IBM

- In the quantum sphere, IBM the Quantum Composer and the IBM Quantum Lab (previously known collectively as the IBM Quantum Experience) form an online platform allowing public and premium access to cloud-based quantum computing services provided by IBM Quantum.
- This includes access to a set of IBM's prototype quantum processors, a set of tutorials on quantum computation and access to an interactive textbook.
- As of February 2021, there are over 20 devices on the service, six of which are freely available to the public.
- This service can be used to run algorithms and experiments and explore tutorials and simulations around what might be possible with quantum computing.

2. Google Quantum AI

- Along with IBM, Google Quantum AI is a leading player in full-stack capabilities in quantum computing.
- Google Quantum AI is advancing the state of the art of quantum computing and developing the tools for researchers to operate beyond classical capabilities.
- The nerve center for Google's quantum activities is The Quantum Artificial Intelligence Lab, a joint initiative between Google, NASA and the Universities Space Research Association, it was founded in 2013 and was the one responsible for the announcement it had achieved **quantum supremacy** back in October 2019.

- Google’s software and hardware are specifically designed for building novel quantum algorithms to help solve near-term applications for practical problems.
- These include **Cirq**, a Python software library for writing, manipulating, and optimizing quantum circuits, and then running them on quantum computers and quantum simulators;
- **OpenFermion**, a library for compiling and analyzing quantum algorithms to simulate fermionic systems, including quantum chemistry; and **TensorFlow Quantum (TFQ),** a quantum machine library for rapid prototyping of hybrid quantum-classical ML models.

- The goal of Google Quantum AI is to pioneer research on how quantum computing might help with machine learning and other difficult computer science problems.
- The lab is hosted at NASA's Ames Research Center.
- Part of Google's strategy included its quantum roadmap.

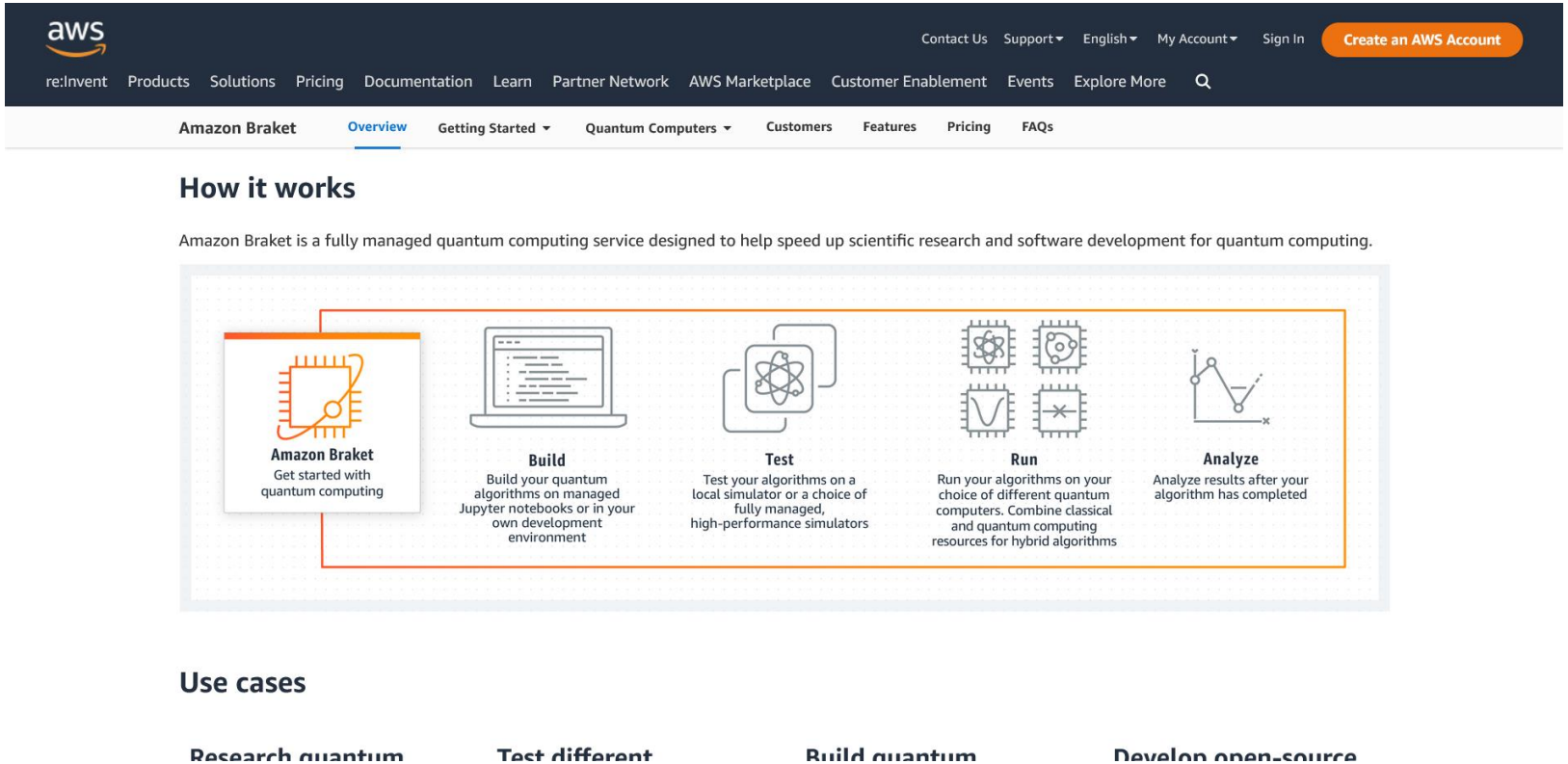
3. Microsoft

- Another of the big players, Microsoft is the provider of the world's first full-stack, open cloud quantum computing ecosystem, featuring solutions, software and hardware delivered through Azure.
- Although Microsoft was founded in 1975, the roots of Microsoft's research into quantum had two teams interested in quantum computing, the QuArC team based in Redmond, Washington. The team explored the construction of quantum circuitry.
- The second, located in Santa Barbara which was researching topological quantum computing.

- In September 2017, during a Microsoft **Ignite** Keynote, Microsoft announced the imminent release of a new quantum computing programming language, Q#, which was eventually rolled out in December of that year, as part of the company's Quantum Development Kit.

4. AWS Braket

- Amazon Braket is a fully managed quantum computing service designed to help speed up scientific research and software development for quantum computing.



- Amazon Braket is a service that provides access to different types of quantum computers to customers via the cloud.
- Available since 2020, the AWS Braket service allows anyone to open an account, log in and pay as you go using the quantum cloud service that leverages quantum annealers from D-Wave, IonQ’s gate-based ion-trap processors, the gate-based superconducting processor offering from Rigetti Computing and Oxford Quantum Circuits, and the gate-based photonic quantum computers from Xanadu.

- Other features include a hardware-agnostic developer framework, which simplifies the process of designing and executing quantum algorithms, fully managed Jupyter notebooks, pre-built algorithms and tutorials, a choice of simulation tools, and many other interesting possibilities.

5. Alibaba Group

- Partnering with the Chinese Academy of Science, Alibaba Group's cloud computing subsidiary has established the Alibaba Quantum Computing Laboratory in Shanghai, China. A member of the international quantum computing community the Alibaba Group's quantum efforts embrace the idea of open-source projects in the space
- In charge of all this is Yaoyun Shi, Head of Quantum Lab, where he leads projects that include the Alibaba Cloud Quantum Development Platform (ACQDP) — a simulator-driven development tool for quantum algorithms and quantum computers.

6. Atos Quantum

- Atos Quantum is a group within the French multinational company Atos that specializes in quantum technology.
- Atos Quantum has released a product called the Atos Quantum Learning Machine, a classical computer that can simulate a quantum system using anywhere between 30 and 40 qubits, depending upon the specific configuration.
- Associated with this product, Atos Quantum provides a universal quantum assembly programming language called AQASM along with other software to allow researchers, engineers, and students to develop and experiment with quantum software.

- In the field of quantum hybridization, Atos Quantum is the only player already enabling several applications — in the areas of chemistry, such as catalysis design for nitrogen fixation, and for the optimization of smart grids. Atos is also involved in two additional quantum hybridization projects, which are currently being launched.

- Atos is one of the first quantum computing companies to adopt a hardware-agnostic approach in developing quantum-powered supercomputers, *as well as providing end-user applications*.
- Atos' ambition is to be a major player in multiple domains among which are quantum programming and simulation, the next-generation quantum-powered supercomputers, consulting services, and of course, quantum-safe cybersecurity.

7. Baidu

- Like Alibaba, Baidu comes from China. Its quantum program includes the launch of an **institute for quantum computing** dedicated to the application of quantum computing software and information technology.
- Called the Baidu Quantum Computing Institute led by Professor Duan Runyao, who had been the director of the Centre for Quantum Software and Information at the University of Technology Sydney (UTS), Baidu's intention is to see quantum technology useful across several verticals like artificial intelligence (AI) and machine learning (ML).

- Baidu says it has designed a quantum hardware-software integration solution.
- The system can plug in and used by other third-party quantum computers, including a 10-qubit superconducting quantum device and a trapped ion quantum device developed by the Chinese Academy of Sciences.

8. Intel

- Intel is working on both superconducting and spin qubits, though research on superconducting seems to be limited to their academic affiliations at Qutech (Delft university), whereas spin qubits are the main focus with activities at Qutech and in-house.

```python
# Import pyQuil modules
from pyquil.quil import Program
from pyquil.api import QVMConnection
from pyquil.gates import H
from functools import reduce

# Create a connection to the Quantum Virtual Machine (QVM)
qvm = QVMConnection()

# Apply the Hadamard gate to three qubits to generate 8 possible randomized results
dice = Program(H(0), H(1), H(2))

# 8 possible results: [[0,0,0], [0,0,1], [0,1,1], [1,1,1], [1,1,0], [1,0,0], [0,1,0]] [0,0,1]]
# Measure the qubits to get a result, i.e. roll the dice
roll_dice = dice.measure_all()

# Execute the program by running it with the QVM
result = qvm.run(roll_dice)

# Example result: [[0,1,0]]
# Format and print the result as a dice value between 1 and 8
dice_value = reduce(lambda x, y: 2*x + y, result[0], 0) + 1
print("Your quantum dice roll returned:", dice_value)
```

quantum_dice.py