

RESEARCH REVIEW 2019

Projecting Quantum Computational Advantage Versus Classical State of the Art

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What is Quantum Computing?

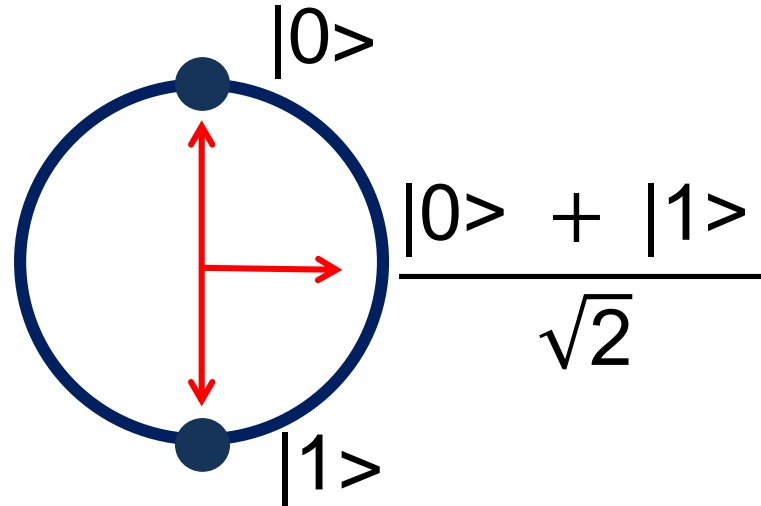


What is Quantum Computing?

● 0

● 1

Cbit



Qubit

- superposition
- **entanglement**

Q1 x q2 =

|00> |01>

|10> |11>

Q1 x q2 x q3 =

|000> |001> |010>

|011> |100> |101>

|110> |111>

...

**q0x...q53 = 2⁵³ states
(PetaScale)**

Noisy Intermediate-Scale Quantum (NISQ) computers aim to perform computational tasks beyond the capabilities of the most powerful classical computers, thereby achieving “Quantum Supremacy,” a major milestone in quantum computing

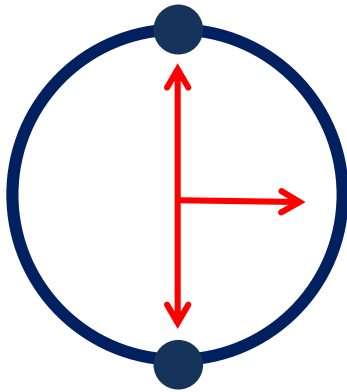
—Villalonga, B.; Lyakh, D.; Boixo, S.; & Neven H. “Establishing the Quantum Supremacy Frontier with a 281 Pflap/s Simulation.”

Universal Gate Quantum Software Engineering



Quantum Computing Education

- By [some estimates](#), fewer than **25,000** people can be considered genuine experts in **deep learning**.
- There are even fewer experts in the field of **quantum computing**.
- Some accounts estimate that only **1000** people worldwide can legitimately claim to be involved in leading research in the field.



Applications

Quantum High-Level Language

Intermediate Representations

Emulator

QC (QPU)

Why Quantum Computing?



Quantum Supremacy?

Quantum Supremacy is the demonstration of superiority over a classical computer on some narrow (but well-defined) task.

Google it (literally and figuratively).



Quantum Supremacy

Quantum Advantage refers to a quantum computer reaching a better “quality” of solution, or reaching a solution faster than a classical computer, for a **USEFUL** problem.

Quantum Advantage: Cryptography

Gidney, Craig & Eker, Martin. “How to Factor 2048 Bit RSA Integers in 8 Hours Using 20 Million Noisy Qubits.” May 24, 2019

The RSA (and some other) encryption protocols *might* be vulnerable over a 10-20 year time frame.

However...



Shor's

NIST is currently reviewing post-quantum encryption protocols.

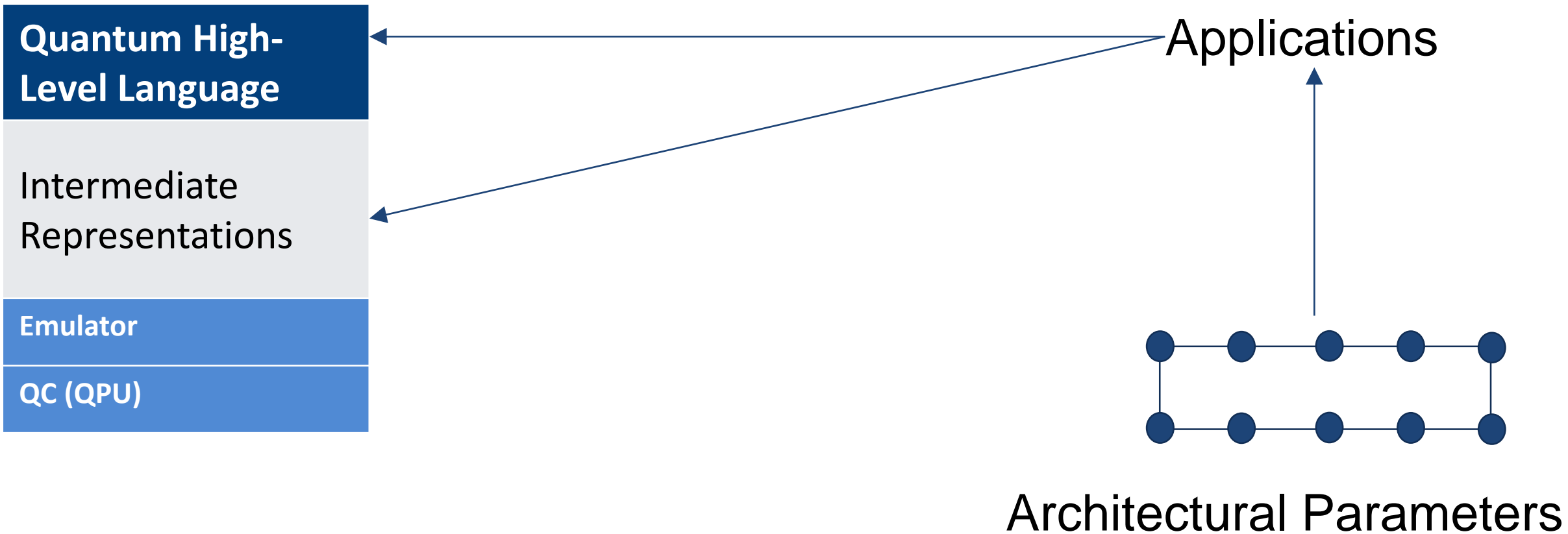


This projection is a demonstration of **quantum advantage**: doing something **useful** that classical computers will never be able to. What other applications will we find with this type of **quantum advantage**?

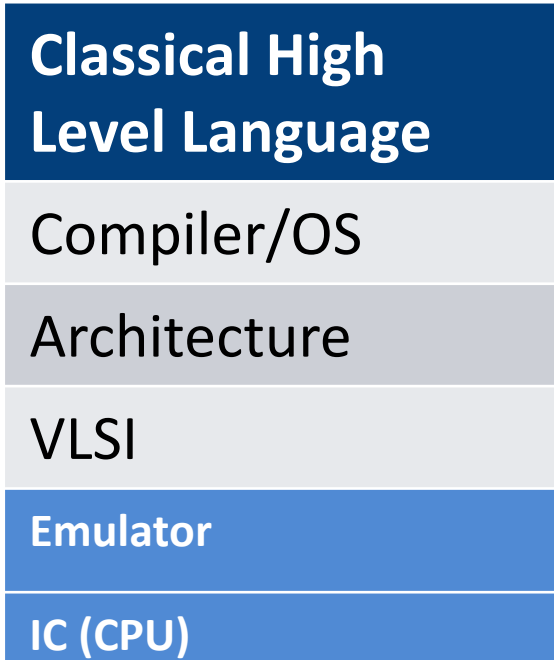
Quantum Computing in the NISQ Era



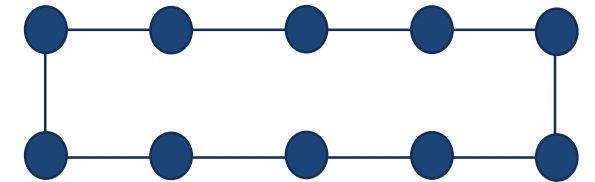
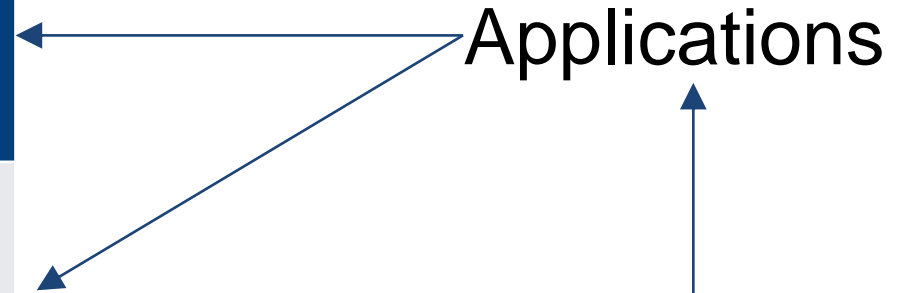
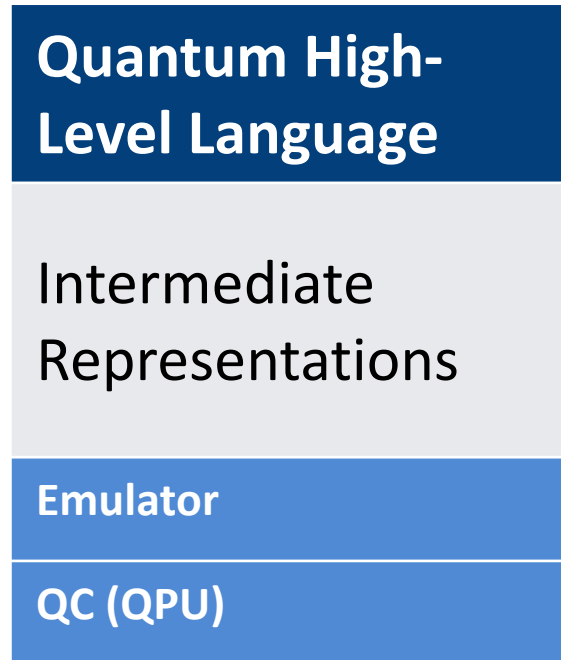
Quantum Software Engineering in NISQ Era



Quantum Advantage: Classical State of the Art



- 60+ year benchmarks
- Software Defined Hardware (SDH)
 - Dr. Tom Rondeau
- Combinatorial Optimization
- Graph Analytics
- AI/ML

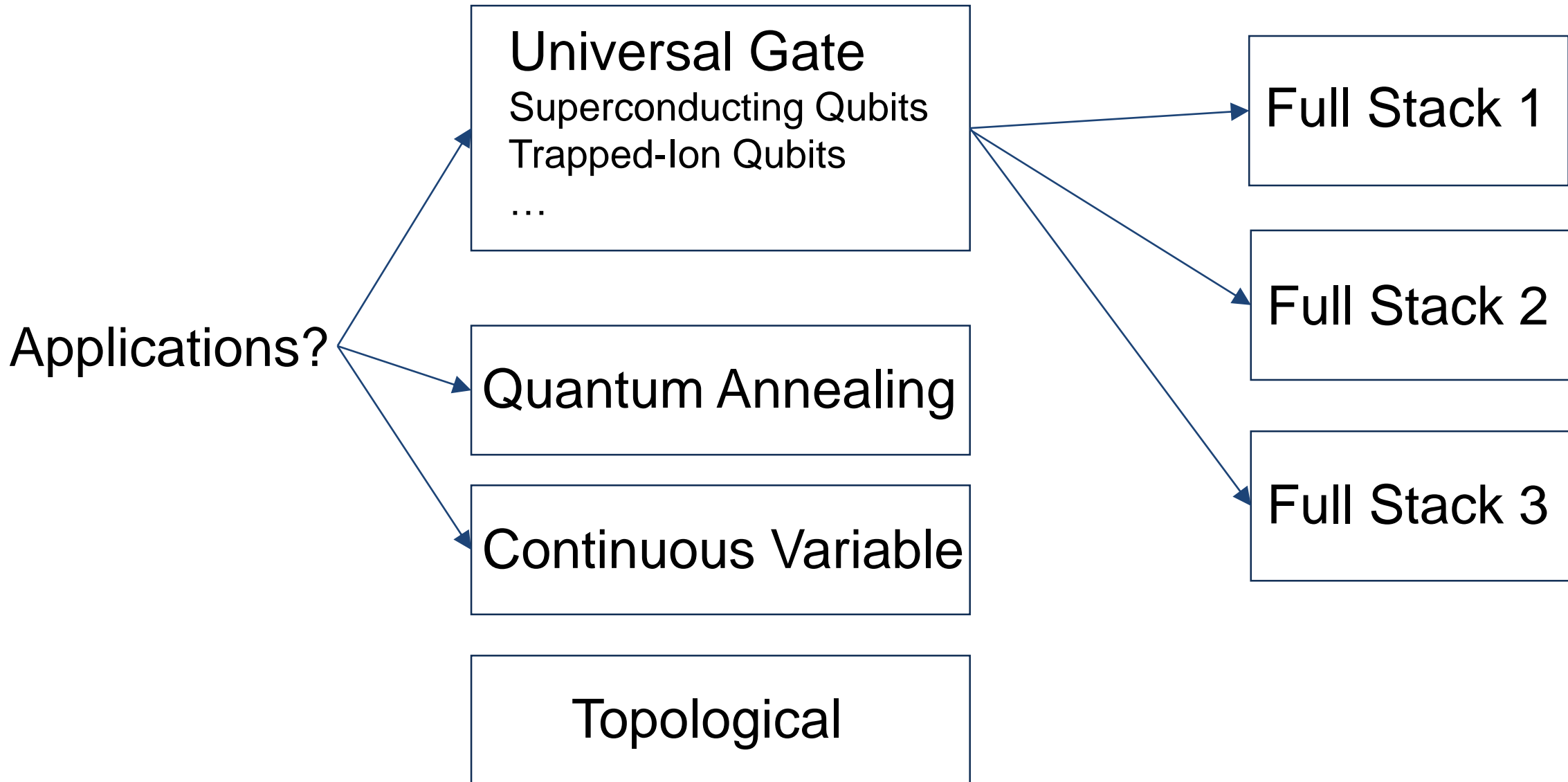


Architectural Parameters

Quantum Computing at the SEI and the DoD: The Future



Quantum Computing Has (or Will Have) Many Forms



Quantum Computing Education

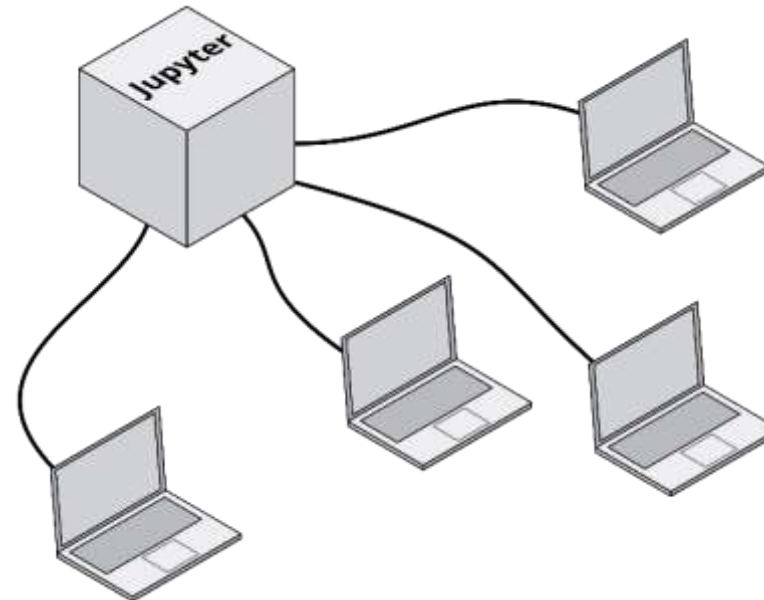
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QuantumHub

Only **1000** people worldwide can legitimately claim to be involved in leading research in the field of quantum computing.

- SEI: 30 users
CMU: 15 users
- ECE
 - Physics
 - CS
 - MatSci

<https://quantum.etchub.xyz>
<https://qhub.xyz>



Noisy Intermediate-Scale Quantum (NISQ) Computers

