Comment on *An IEEE Framework for Metrics and Benchmarks of Quantum Computing* Version 0.2

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Firstly, I would like to begin by thanking the contributors to the IEEE framework. It is indeed important that we make the framework around metrics and benchmarks concrete. It will better enable the field to track progress internally and externally which leads to better decision making in developing this important technology. Thanks for getting this started.

Now, on to the comments!

[0] Denoting Boundaries of NISQ

Table 2 lists NISQ devices as 50-100 qubits with noisy gates. I propose that this is too restrictive of a definition for the NISQ category. Generally, NISQ should refer to the era where a programmer must be closely concerned with the details of gate noise, i.e. where they cannot blindly abstract away the noise model to imagine they are programming fault-tolerant qubits. This can occur when there are high error rates or where there are limited qubits. Even when quantum error correcting codes are being run limitations on available quantum memory will mean the programmer must be concerned with how qubits are allocated to perform the error correction.

Indeed, Preskill originally introduced the term as "qubits ranging from 50 to a few hundred" [2], but I suggest that we should go a bit further. I propose that the term *NISQ era refer to devices where average error rates are greater than 10^{-5} and that have up to 10k qubits.*

Note that the suggested error rate boundary is significantly below known error correction thresholds, e.g. 10^{-2} for the surface code. There are a couple reasons for this (a) thresholds are typically calculated for theoretical error models that may not hold exactly in practice (b) one must be below the threshold to see the benefits of error suppression and (c) average error rates can hide unfavorable distributions of errors that can hurt the performance of a code. That said errors are typically suppressed exponentially below the threshold so an extra three orders of magnitude should give enough breathing room that below 10^{-5} one is more in the fault-tolerant regime and less in the NISQ regime.

The qubit cutoff is proposed around 10k. Here one can have approximately 200 logical qubits encoded with the distance 7 surface code. At this size one can consider abstracting to fault-tolerant algorithms.[3] It is at this scale and performance that current error correcting codes could be applied to relatively large blocks of memory and the programmer could work relatively freely at the logical level.

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[2] https://arxiv.org/abs/1801.00862
[3] https://arxiv.org/pdf/1208.0928.pdf

[1] Renaming the Physical Circuit Layer
Generally I think these are great technology layer distinctions. One concern is that the term “Physical Circuit” could be a confusing one as it has overloaded terminology. In particular, superconducting circuit implementations of quantum processors already refer to the chip as a physical circuit, i.e. the layout of Josephson Junctions, resonators, etc. on silicon. Using “Physical Circuit” in the abstract meaning proposed in the document could add unneeded confusion.

I propose that the term *Physical Network* be used instead.

[2] A Proposal for Clarifying the terms used to compare classical and quantum performance
Much has been made of the term *quantum supremacy* and I would propose that the group consider clarifying this term as part of the benchmarking framework. In particular, I would propose that four separate terms be clarified and adopted. These terms will speak to milestones that are relevant academically as well as milestones that are relevant industrially:

- *Quantum Supremacy:* This milestone consists of two results: (1) a mathematical proof that a given problem has exponential separation between any possible quantum algorithm and any possible classical algorithm and (2) the exhibition of the solution of this problem by a quantum computer at a scale that is infeasible with any available classical computer.
- *Weak Quantum Supremacy*: The solution of any problem, using a quantum computer, faster, cheaper, or more efficiently than any available classical solution.
- *Quantum Advantage*: Weak Quantum Supremacy but for a commercially valuable problem not just one of esoteric mathematical or benchmarking interest.
- *Strong Quantum Advantage*: Quantum Advantage but with a proof that the problem has an exponential separation between any quantum solution and any classical solution.

These four terms form the following table:

	Practical	Foundational
Any Problem	**Weak Quantum Supremacy**	**Quantum Supremacy**
Valuable Problems	**Quantum Advantage**	**Strong Quantum Advantage**

It is critical that we clarify these major milestones both externally and internally to the field and it is hoped that the proposed terms will bring a little clarity to this effort.

I hope that the group finds these informal comments helpful.