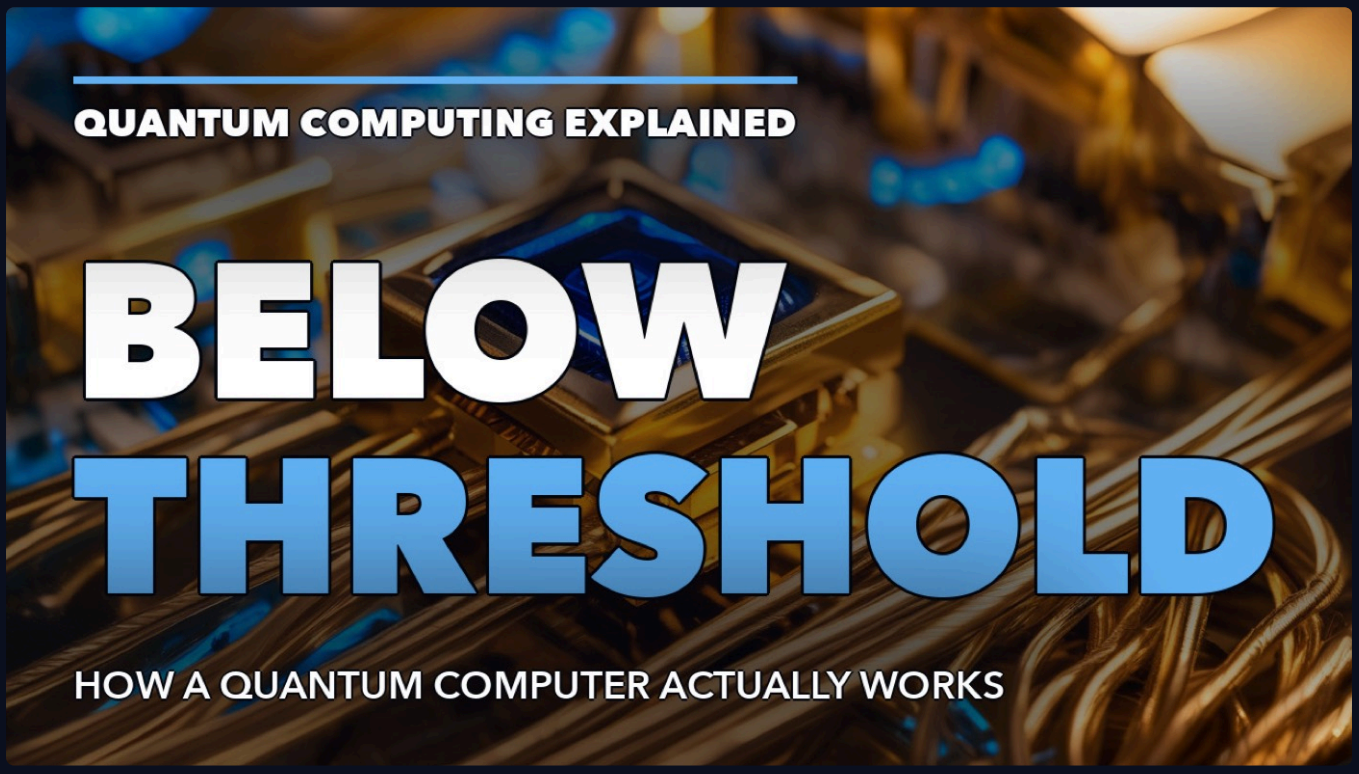
Forwards or Backwards

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How a Quantum Computer Works

Watch on YouTube: https://www.youtube.com/watch?v=FHOo6Vmy62E

A quantum computer replaces the ordinary bit, a switch that is either zero or one, with a qubit: something that holds both at once until it is measured. This video explains what that actually means, why building one is so hard, and where the technology genuinely stands today.

First the mechanism: superposition, measurement, and entanglement, explained without the shortcuts that make the subject sound more mysterious than it is. Then the physical machine - superconducting qubits cooled near absolute zero, and decoherence, the fragility that has limited the field since it began.

Then the milestone: Google's Willow chip, reported in Nature on 9 December 2024, was the first real device where adding more physical qubits made the error rate go down rather than up - 'below the

surface code threshold'. Its logical qubit lasted 2.4 times longer than its best individual physical qubit.

Then the plan: IBM's roadmap, published 10 June 2025, targets a machine called Starling for 2029 - 200 logical qubits, 100 million quantum operations - and a later machine, Blue Jay, with no date given.

And the contested claim: Microsoft's Majorana 1 chip, announced February 2025, claims a sturdier kind of qubit. Nature published a formal challenge to the evidence, echoing a near-identical claim from 2018 that was later retracted. This video reports it as contested, not settled - neither side has closed the question.

Finally, what any of this is actually for: a narrow set of problems with a known quantum algorithm, including factoring the large numbers behind today's internet encryption - the subject of this channel's companion video, 'The Quantum Threat to the Internet', which this video does not repeat.

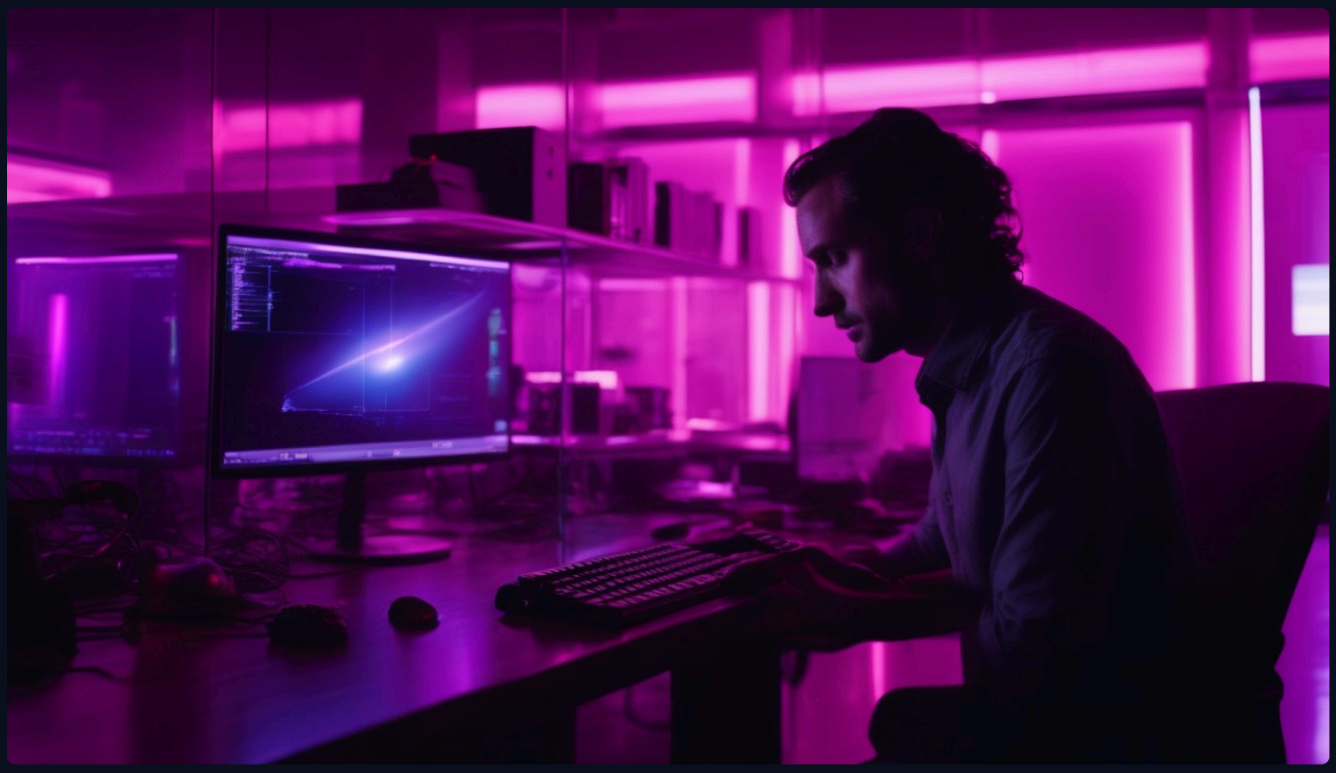
No figure appears without its date, unit and source. A contested claim is presented as contested.

Educational documentary. Not financial or investment advice.

Chapters

1. The bit that will not settle
2. Two answers, until one is measured
3. Wired together
4. A machine kept colder than space
5. Physical qubits, and the one that matters
6. Below threshold
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1. The bit that will not settle



Every computer you have ever used, from a phone to the largest data centre, runs on a bit. A bit is a switch. It is either off or on, zero or one, and at any moment you could stop the machine and read every switch's answer.

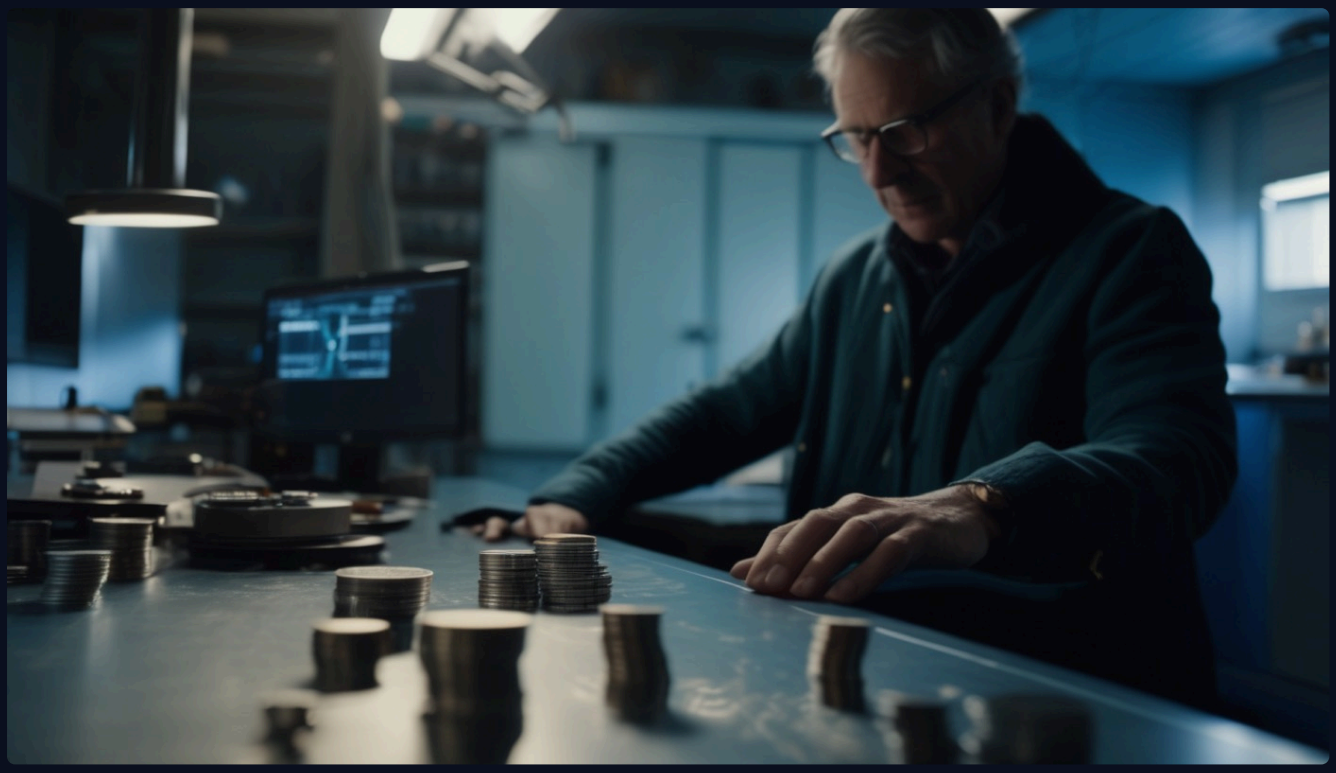
A quantum computer replaces that switch with something called a qubit, short for quantum bit. While nobody is looking at it, a qubit does not hold zero or one. It holds both at once, in a combination called a superposition, and the moment you measure it, that combination produces one answer or the other.

That single change, from a switch to something that resists being pinned down until you look, is the whole of what makes a quantum computer different.

This video covers four things. What a qubit actually is, and why building one is so hard. How today's machines catch and correct their own errors, for the first time. The published plans to build something far bigger. And the one contested claim in the field right now, reported honestly as contested.

We start with the idea itself, before any hardware at all.

2. Two answers, until one is measured



Physicists often introduce superposition with a spinning coin. While it spins, it is not showing heads or tails. It only becomes one or the other when it lands and you look.

That picture is useful, and it is also wrong in an important way, so it is worth being precise about where it breaks down.

A spinning coin really is heads or tails the whole time; you simply have not looked yet. A qubit is not secretly zero or one before you measure it. The combination is the actual, complete description of the qubit, and measurement is not a discovery of a hidden fact. It is the point at which one of the two possible outcomes gets produced.

Nobody has ever measured a qubit mid-superposition and seen the combination directly. Every experiment agrees with the mathematics that describes it, and none has ever caught it holding still.

One qubit on its own is not very useful. Its power comes from combining many qubits, so that the combination of all of them together can represent an enormous number of possibilities at once, and certain calculations can explore many of those possibilities in parallel rather than one after another.

That is the promise. Building the hardware to deliver it is a separate, much harder problem.

3. Wired together



Qubits can also be linked to each other in a way with no equivalent in ordinary computing, called entanglement.

Two entangled qubits have measurement outcomes that are correlated with each other, however far apart the two qubits physically are. Measure one, and the statistics of the other are tied to it in a way that no shared instruction sheet, written in advance, could reproduce.

That correlation is real and it has been measured directly, many times, so it is not in dispute. What it is not, is a channel for sending a message. Nothing about entanglement lets one qubit's measurement tell you anything until someone compares notes by ordinary means, at ordinary speed.

So entanglement is not communication, and it is not magic. It is a mathematical property of the combined system, confirmed by experiment, and quantum computing uses it as a resource, the way ordinary computing uses wires between transistors.

With those two ideas, superposition and entanglement, the theory of a quantum computer is complete. Building one is where the real difficulty starts.

4. A machine kept colder than space



A qubit has to be built from something physical, and the leading approach, used by both Google and IBM, is a tiny superconducting circuit etched onto a chip.

That chip is cooled inside a dilution refrigerator to a temperature close to absolute zero, colder than deep space. The reason is simple: heat is motion, and any stray motion is enough to knock a fragile superposition apart before a calculation finishes.

That destruction of the quantum state has a name, and it is the single biggest obstacle in the entire field.

It is called decoherence, and every known qubit suffers from it. A superconducting qubit today stays usable for a tiny fraction of a second before decoherence corrupts it, so any calculation has to finish, or be protected, well inside that window.

That is not a flaw in one company's chip. It is a property of the physics, and it is why the next part of this story is about correcting errors rather than avoiding them.

5. Physical qubits, and the one that matters



Because a single physical qubit is so fragile, nobody tries to compute directly on one.

Many physical qubits are wired together, following a mathematical pattern called a code, to behave as one more reliable logical qubit. The logical qubit is the one an actual calculation would use. The physical qubits underneath it are there purely to catch and correct each other's errors.

For years, adding more physical qubits to a code made things worse, not better: more parts meant more chances for something to go wrong, and the correction could not keep up.

The point at which adding more physical qubits finally starts reducing the error rate, instead of increasing it, is called crossing the threshold. Until a device crosses it, scaling up a quantum computer makes it less reliable. After it, scaling up makes the answer more trustworthy.

Reaching that point, for real hardware rather than just in theory, took years.

6. Below threshold



Google's Quantum AI team published the result in Nature on the ninth of December twenty twenty-four.

The chip was called Willow. On a hundred and five qubits, arranged into a code a hundred and one qubits wide, each step up in the code's size cut the error rate by a factor of about two.

That factor is the headline number, and it is worth saying exactly what it means, because it is easy to overstate.

The paper reports the logical qubit lasting two point four times longer than the best individual physical qubit it was built from, before an error occurred. Its title says exactly that: "Quantum error correction below the surface code threshold." That is what "below threshold" means in practice: the whole is now more reliable than any one of its parts.

Google also announced, the same day, that a separate benchmark task took the chip about five minutes to run.

Google's own estimate is that the same task would take a leading supercomputer about ten septillion years. That figure is the company's own calculation for one specific, narrow benchmark, not an independent measurement, and not a claim that Willow beats ordinary computers at anything useful. The error-correction result, not this figure, is what the rest of the field treats as the milestone.

Crossing the threshold answered one question. It immediately raised the next one: how big does this have to get?

7. The plan to 2029



IBM published its own answer on the tenth of June twenty twenty-five, as a dated roadmap rather than a finished machine.

IBM's plan names a system called Starling, targeted for twenty twenty-nine, built at a new IBM Quantum data centre in Poughkeepsie, New York. IBM says Starling is designed to hold two hundred logical qubits and run a hundred million quantum operations.

Two hundred logical qubits sounds small next to the hundred and five physical qubits Willow already has, and that gap is the entire point.

A single logical qubit, reliable enough to trust, currently needs many physical qubits working together to protect it. IBM says a newer error-correcting method, based on a different kind of code, cuts that overhead by about ninety per cent compared with the approach Willow uses.

Whether that saving holds up at Starling's scale is exactly what the next four years are meant to test. IBM names one further, later machine, with no date attached.

IBM calls the machine planned after Starling "Blue Jay": two thousand logical qubits, a billion quantum operations, and no year given for it in the company's own material.

A roadmap is a plan, not a delivered result, and this video treats it that way throughout.

8. A contested claim



Not every announcement in this field has held up, and the honest way to cover this subject is to say so.

In February twenty twenty-five, Microsoft announced a chip called Majorana 1, describing it as the first quantum processor built on what the company calls a topological core, holding eight qubits. A topological qubit, if it can be built, would in theory resist decoherence far better than the superconducting qubits this video has already covered.

That claim did not go unchallenged.

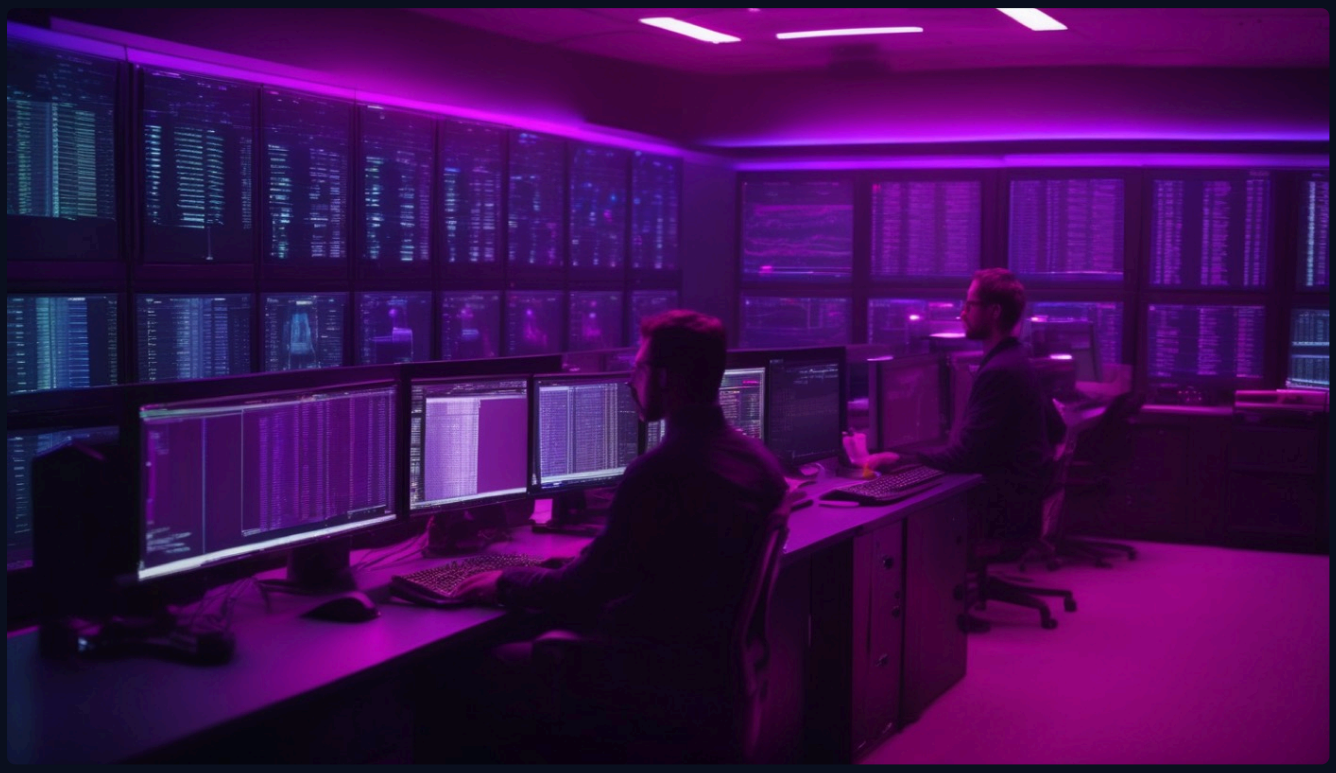
Nature published a formal challenge to the underlying evidence. The dispute is specific. The measurements Microsoft published do not, on their own, tell apart a genuine Majorana state from an ordinary state that can look similar on this kind of test but does none of the useful work.

This is not the first time this exact question has come up for this exact kind of claim.

A Microsoft-linked team published a paper in Nature in twenty eighteen claiming firm evidence of the same effect. That paper was later retracted, after the same data turned out to fit the ordinary explanation just as well. Neither side of the twenty twenty-five dispute has settled the question, and this video does not settle it either.

That is where the contested part of the field stands. The next question is what any of this is actually good for.

9. What it is actually for



A quantum computer is not a faster version of the computer in your pocket, and this video has been careful throughout not to suggest that it is.

The advantage, where it exists, is narrow: a small number of specific problems have a known quantum algorithm that beats every known classical method. Simulating another quantum system, such as a molecule, is one. Searching an unsorted list a little faster is another. Most everyday computing tasks have no such advantage and gain nothing from this hardware.

One of those narrow problems is the reason this channel made a companion video at all.

A quantum algorithm exists that could, in principle, factor the very large numbers that today's internet encryption depends on, far faster than any classical computer can. No machine built so far, including Willow, is remotely close to large enough or reliable enough to run it against real encryption. That is the whole subject of "The Quantum Threat to the Internet", and this video will not repeat it here.

So the two videos divide cleanly: how the machine works, and what it would mean if a big enough one existed.

10. Where it actually stands



Put the pieces from this video together, and the picture is neither the finished machine some coverage implies, nor nothing at all.

A real device has crossed the threshold where adding more qubits makes it more reliable rather than less. A major company has published a dated, numbered plan for a far larger machine, five years out. And at least one headline claim in the field remains an open, published scientific dispute, exactly as this video has reported it.

None of that adds up to a working, general-purpose quantum computer today.

What exists today is a demonstrated physical mechanism, and a roadmap toward the scale that mechanism would need to matter. The gap between those two things, physics that works and a machine big enough to use it, is the honest state of quantum computing in twenty twenty-six.

That gap is not a failure. It is where the field actually is, and it is why both halves of this story, the mechanism and the consequence, are worth thirty minutes of anyone's time.

Sources and credits

Primary sources

- Google Quantum AI and collaborators, 'Quantum error correction below the surface code threshold', Nature, published online 9 December 2024 (nature.com/articles/s41586-024-08449-y) - Willow chip; 72-qubit (distance-5) and 105-qubit (distance-7, 101-qubit code) processors; error suppression factor Lambda = 2.14 +/- 0.02 per code-distance step; logical error rate 0.143% +/- 0.003% per cycle at distance 7; logical qubit lifetime 2.4 +/- 0.3 times its best physical qubit.
- Google, same-day announcement (9 December 2024) - benchmark sampling task, about five minutes on Willow, company estimate of about 10 septillion (10^25) years on a leading classical supercomputer for the same task. Reported as Google's own estimate for one benchmark, not an independent measurement.
- Microsoft, Majorana 1 announcement, February 2025 - described by Microsoft as the first quantum processor built on a 'Topological Core'; eight qubits.
- Background, cross-checked: a Microsoft-affiliated Nature paper (2018) claiming conclusive evidence of Majorana zero modes was later retracted after the same data proved consistent with Andreev states.

Not regulated financial advice.