Oportunidades Globales de Quantum Computing para Costa Rica

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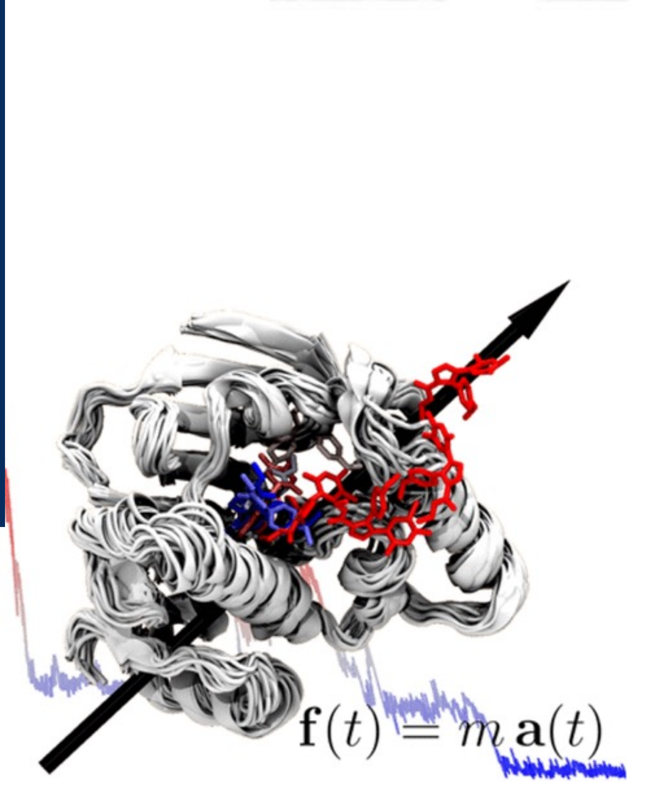
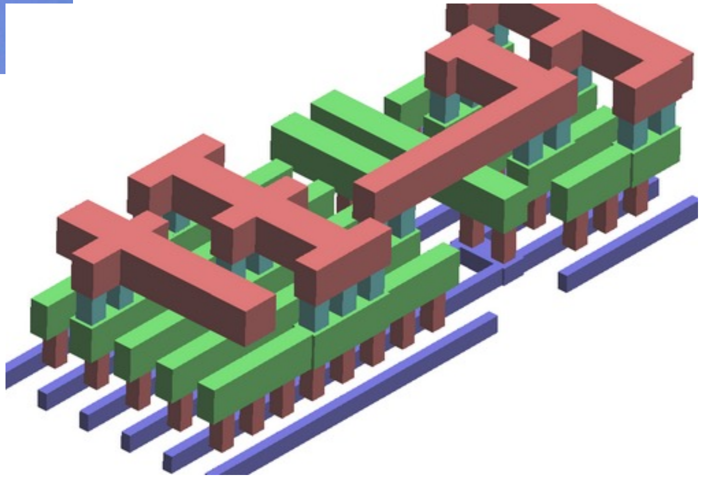
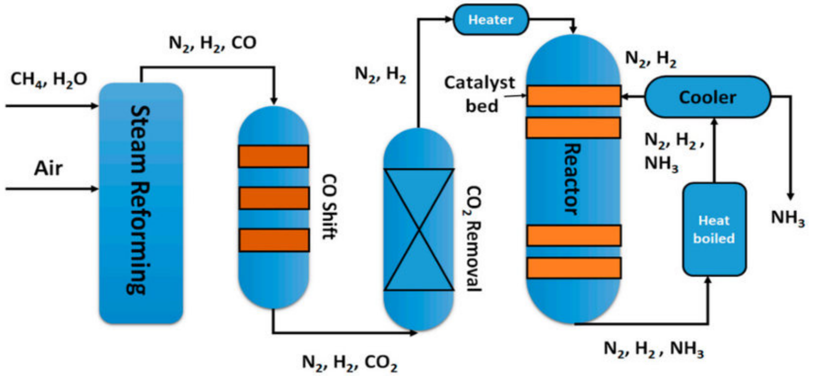
National Center for Supercomputing Applications

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN



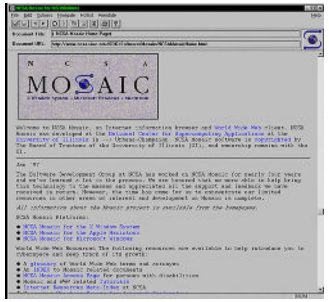




ILLINOIS NCSA

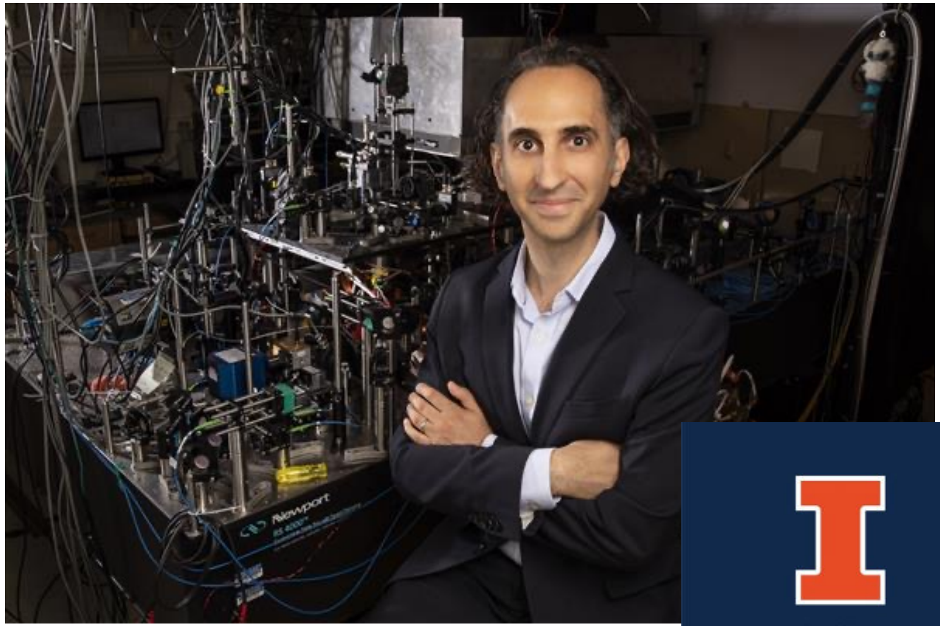
El National Center for Supercomputing Applications

NCSA crea y utiliza tecnologías computacionales del mañana para atacar los problemas más importantes de hoy.

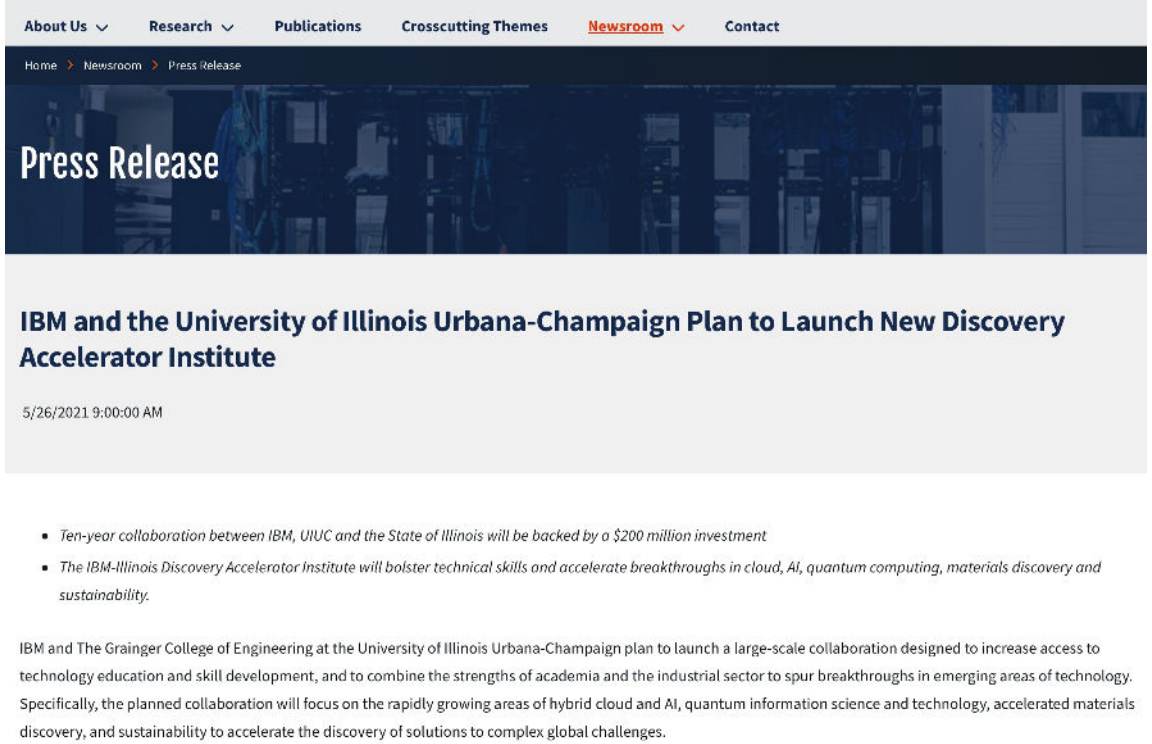


¿Qué sigue?

Quantum computing



IQUIST



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Press Release

IBM and the University of Illinois Urbana-Champaign Plan to Launch New Discovery Accelerator Institute

5/26/2021 9:00:00 AM

- *Ten-year collaboration between IBM, UIUC and the State of Illinois will be backed by a $200 million investment*
- *The IBM-Illinois Discovery Accelerator Institute will bolster technical skills and accelerate breakthroughs in cloud, AI, quantum computing, materials discovery and sustainability.*

IBM and The Grainger College of Engineering at the University of Illinois Urbana-Champaign plan to launch a large-scale collaboration designed to increase access to technology education and skill development, and to combine the strengths of academia and the industrial sector to spur breakthroughs in emerging areas of technology. Specifically, the planned collaboration will focus on the rapidly growing areas of hybrid cloud and AI, quantum information science and technology, accelerated materials discovery, and sustainability to accelerate the discovery of solutions to complex global challenges.

Nuestra misión en Quantum Computing

- Acelerar la solución de problemas donde se materializan ventajas cuánticas en aplicaciones científicas para lograr transferencia tecnológica efectiva dentro de la siguiente década
- Desarrollar investigación única que integra aspectos teóricos y pragmáticos de la interación entre plataformas de cómputo cuántico, problemas, algoritmos y practices humanas necesarias para atacar retos económica y socialmente relevantes
- En el corto plazo, movemos la frontera del estado del arte a través del ecosistema de tecnologías cuánticas para deliminar la hoja de ruta de integración HPC-QC
- Complementamos y extendemos la estrategia de la University of Illinois para mantener liderazgo científico y tecnológico

Visión Integradora: avanzar la computación cuántica para aplicaciones científicas

- Construir más y mejor hardware cuántico
- Hacer el hardware cuántico más accesible
- Integrar supercómputo con hardware cuántico distribuido
- Incrementar la eficiencia intellectual del desarrollo de software cuántico
- Identicar problemas con soluciones cuánticas úniacs
- Entrenar a la comunidad científica e industrial
- Democratizar la computación cuántica en la sociedad

Experiencia de NCSA en simulación, redes y ciberinfraestructura

Experiencia de NCSA en desarrollo de software y consultoría científicas

Experiencia de NCSA en entrenamiento y visualización avanzada

Socios académicos e industriales

IQUIST

GRAINGER ENGINEERING

CHICAGO QUANTUM EXCHANGE

IBM

Amazon Braket

NVIDIA

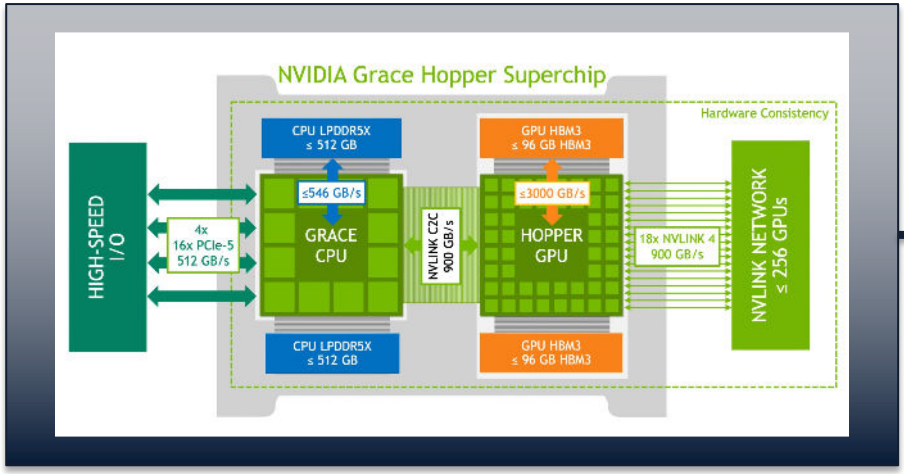
QUANTUM MACHINES

|QuEra⟩ COMPUTING INC.

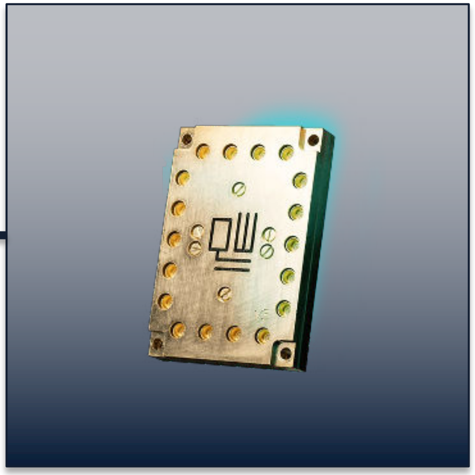
CLASSIQ

1. LCCF
TACC - John Towns, Sandra Kappes, Gregory Bauer, Timothy Boerner

GPU/NCSA



QPU/IQUIST

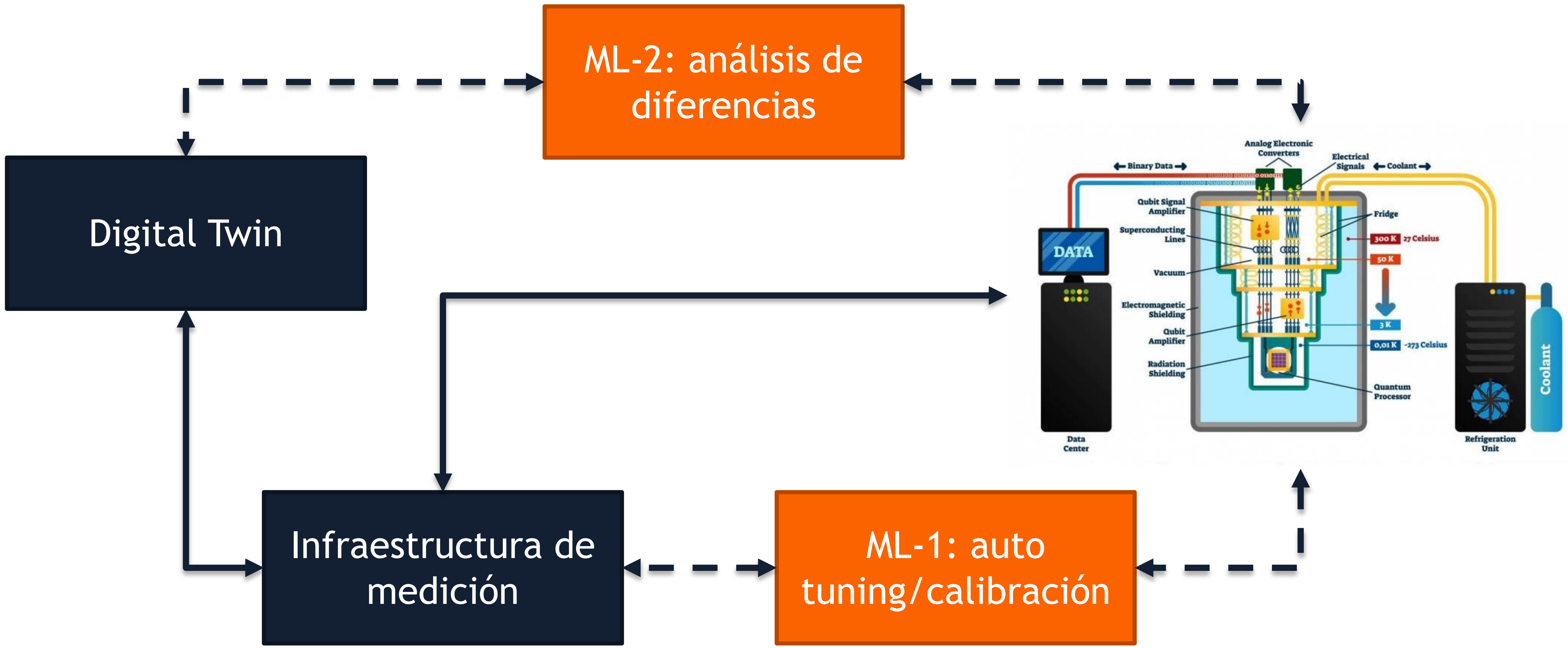


Objetivos:

- Pruebas de integración
- Benchmarking
- Búsqueda de aplicaciones

4. Digital Twins para Quantum Computing Hardware

NCSA Visual Analytics + IQUIST, IIDAI 2023



Oportunidades Globales para Costa Rica

National Center for Supercomputing Applications
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Quantum Hardware, Fabricación

Infactible para CR en 20 años.

- ~$5M anuales en hardware
- Laboratorios especializados
- 5-10 PhDs en física por tecnología
- Reglas ágiles de importación con USA, UK, EU, Singapur

Pero…

★ ★ ★

New Partnership with Costa Rica to Explore Semiconductor Supply Chain Opportunities

MEDIA NOTE

OFFICE OF THE SPOKESPERSON

JULY 14, 2023

The State Department will partner with the Government of Costa Rica to explore opportunities to diversify and grow the global semiconductor ecosystem and create a more resilient, secure, and sustainable global semiconductor value chain. This partnership is enabled by the International Technology Security and Innovation Fund ("ITSI" Fund), created by the CHIPS Act of 2022.

The United States views Costa Rica as a partner in ensuring the semiconductor supply chain can keep pace with the digital transformation underway. Products ranging from vehicles to medical devices increasingly rely on semiconductors as the building blocks of today's economy. This collaboration underscores the significant potential to expand this industry in Costa Rica to the benefit of the United States and Costa Rica.

Quantum Hardware, Compra o Leasing

Infactible para CR en 5-10 años.

- Costo de sistemas $15M-$100M
- 2-3 PhDs en física entrenados por plataforma, facilities especializadas
- Uso exclusivamente experimental con ROI limitado
- Pero:
  - Modelo de servicios por co-charging
  - Atracción de talento

Quantum Hardware, Simulación Clásica de Hardware

Factible para CR en 2-5 años.

- Es un problema de software con spill-overs a otras áreas del CHIPS Act
- Industria de software local que puede entrenarse para solucionar problemas abiertos
- Creación de modelos de hardware cuántico on-demand
- Colaboración con centros de investigación externos de primer nivel

Quantum Hardware, Uso en Cloud

Factibilidad immediata.

- Costo por uso en Azure, AWS, IBM Quantum
- Diferentes modelos de compra de tiempo de QPU
- Gradiente de experimentación y entrenamiento
- Posibilidades inmediatas de entrenamiento

Quantum Software, Control Cuántico

Infactible para CR en 5-10 años.

- Requiere hardware cuántico y experiencia profunda
- ~10 PhDs en física, ingeniería eléctrica/electrónica, ciencias de la computación
- Pero:
  - Admite simulación

Quantum Software, Software Stacks

Factible para CR en 1-5 años.

- Problemas interesantes en embedded systems, compiladores, sistemas operativos
- Innovación gradual o radical es posible
- No existe una receta única o perfecta

Quantum Software, Modelos y Lenguajes de Programación

Factible para CR en 1-3 años.

- Fuerte industria de desarrollo de software en Costa Rica
- Trayectoria previa (Artinsoft)
- Personal académico con formación en esta área
- Requiere personas investigadoras en álgebra superior y quantum field theory para innovación radical

Quantum Software, Quantum Applications

Factibilidad inmediata.

- Materiales de entrenamiento abiertos disponibles
- Uso de la diaspora costarricense
- Fuerte industria de software
- Cámaras industriales reconocidas: CAMTIC, Cámara de Industrias, ABC

Quantum Software, Training para la Comunidad Global

Factibilidad inmediata.

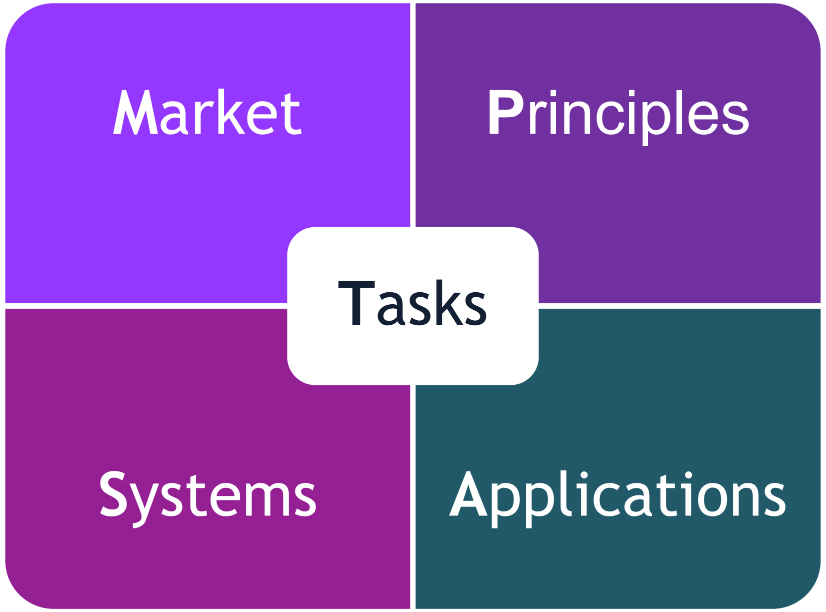
- Mercado abierto para contenidos que permitan llegar de principios cuánticos a aplicaciones
- Plataformas de online learning

Quantum Computing - Recomendaciones

- La oportunidad abierta por el CHIPS and Science ACT es única, y debe aprovecharse para colocar al país al frente de tecnologías estratégicas: quantum es una de ellas
- Una agenda de corto plazo enfocada en entrenamiento y búsqueda de aplicaciones
- Una agenda de largo plazo enfocada en manufacturar hardware cuántico de 10-20 años una vez que la tecnología madure
- Tener dominio no trivial de quantum computing puede abrir oportunidades de mercado insospechablemente fuertes para Costa Rica

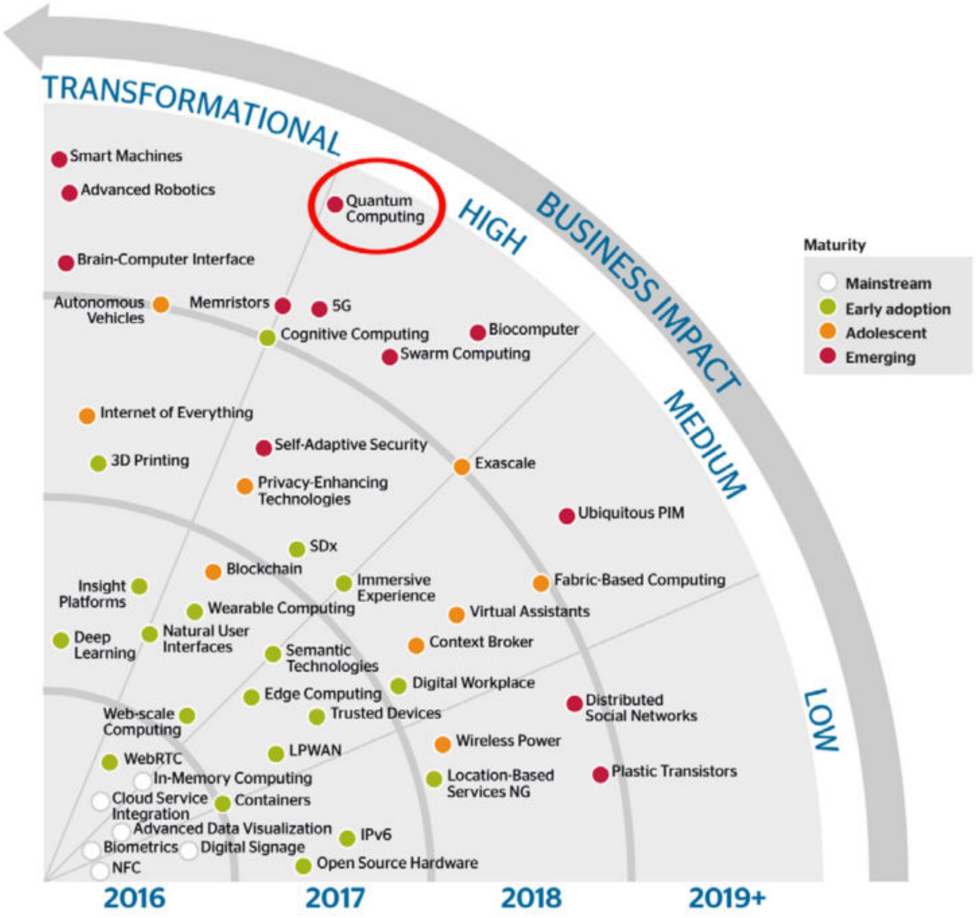
Objetivo de hoy

Una vista a la computación cuántica mediante el lente de MPSAT



Mercado

La computación cuántica se convertirá en una tecnología transformacional

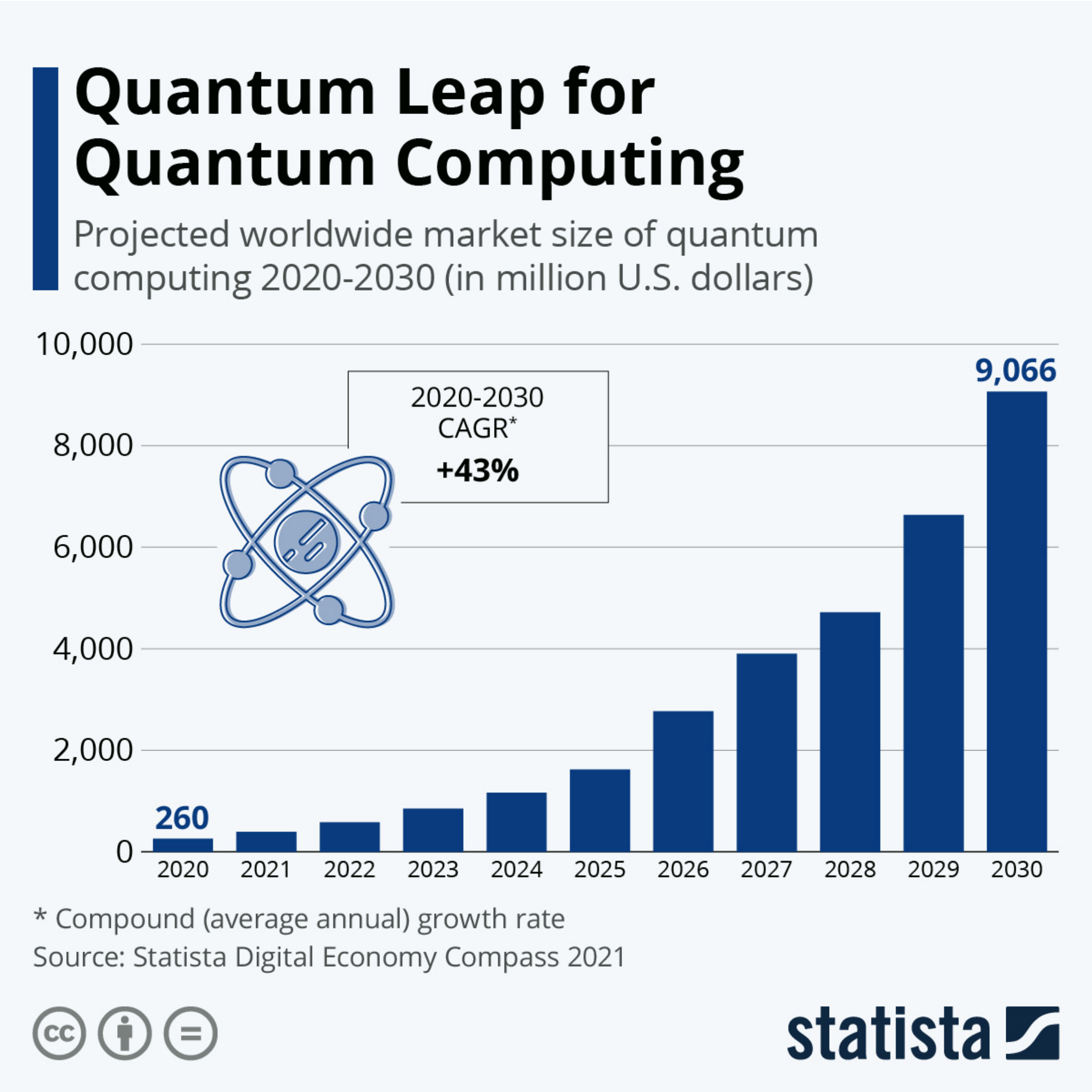


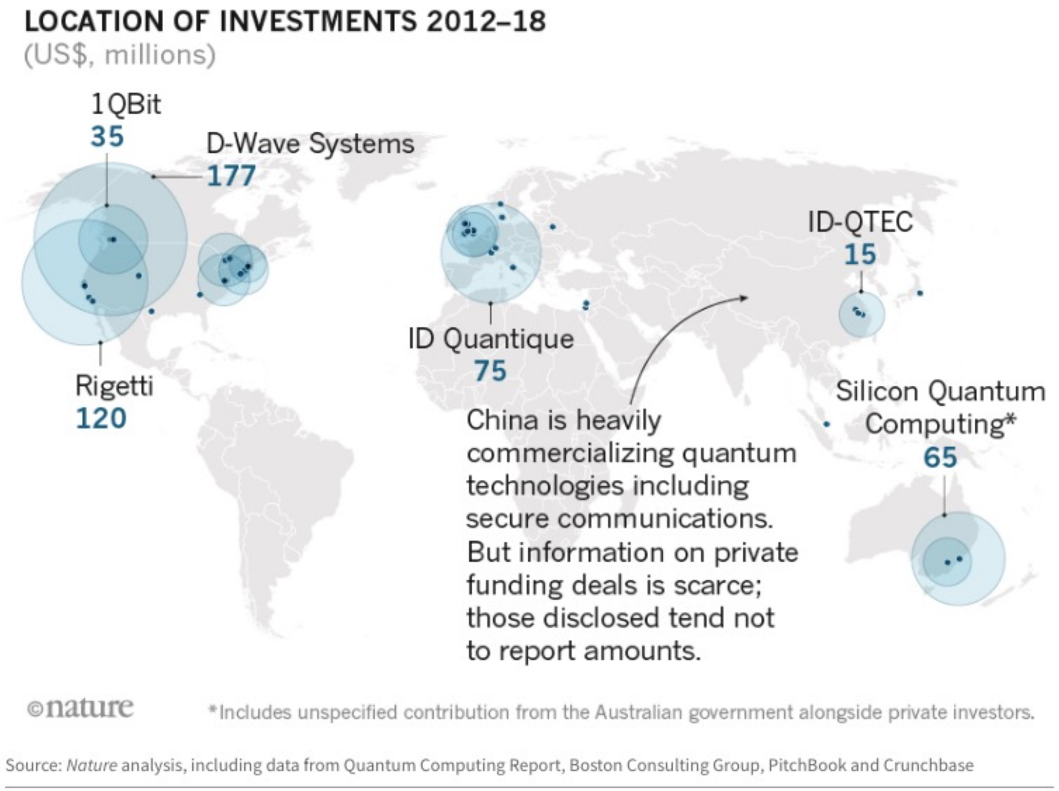
¿Qué atributos caracterizan lo “transformacional”?

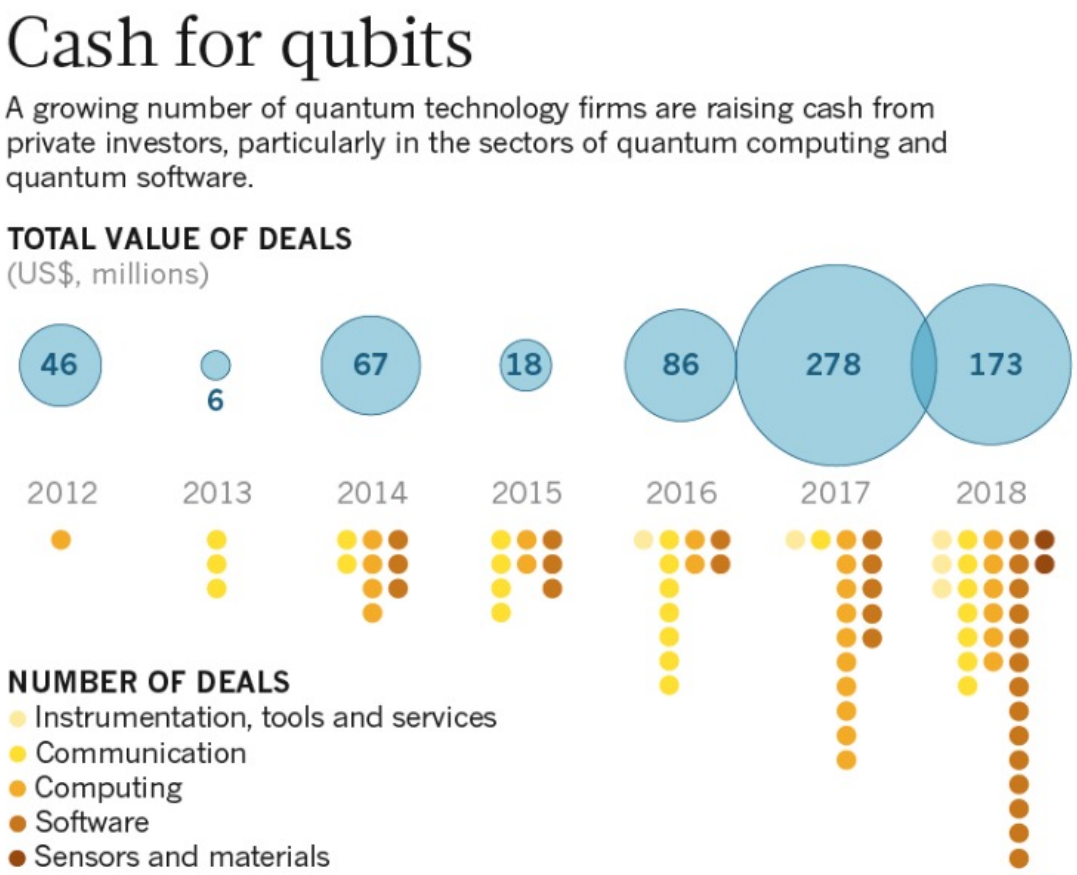
- Rango de aplicabilidad
- Tiempo de solución
- Factibilidad del tamaño de problema
- Capacidad de solución

Quantum se diferencia de lo *clásico* a lo largo de estas dimensiones


GLOBAL QUANTUM COMPUTING MARKET
North America
Largest Market
By Region (2019)
APAC
Fastest-Growing Market
By Region (2020–2030)
2019
Market Size
$89.6
million
2030
Market Size
$1,866.8
million
Market
Growth Rate
(2020–2030)
33.1%


Quantum Leap for Quantum Computing
Projected worldwide market size of quantum computing 2020-2030 (in million U.S. dollars)
10,000
8,000
6,000
4,000
2,000
0
2020-2030 CAGR*
+43%
260
9,066
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
* Compound (average annual) growth rate
Source: Statista Digital Economy Compass 2021
statista





Elizabeth Gibney. **Quantum gold rush: the private funding pouring into quantum start-ups.** Nature, October 2019.

“Quantum technologies are rapidly maturing, with an ever-growing number of governments and businesses launching strategic initiatives and collectively investing more than $35.5 billion across multiple continents.”

⟨quantum|gov⟩

AGENCIES

U.S. AIR FORCE

U.S.ARMY

DARPA

NASA

NSF

NIH

National Institutes of Health

NIST

USDA

132 STAT. 5094 PUBLIC LAW 115–368—DEC. 21, 2018

TITLE I—NATIONAL QUANTUM INITIATIVE

President. 15 USC 8811.

SEC. 101. NATIONAL QUANTUM INITIATIVE PROGRAM.

(a) IN GENERAL.—The President shall implement a National Quantum Initiative Program.

(b) REQUIREMENTS.—In carrying out the Program, the President, acting through Federal agencies, councils, working groups, subcommittees, and the Coordination Office, as the President considers appropriate, shall—

(1) establish the goals, priorities, and metrics for a 10-year plan to accelerate development of quantum information science and technology applications in the United States;

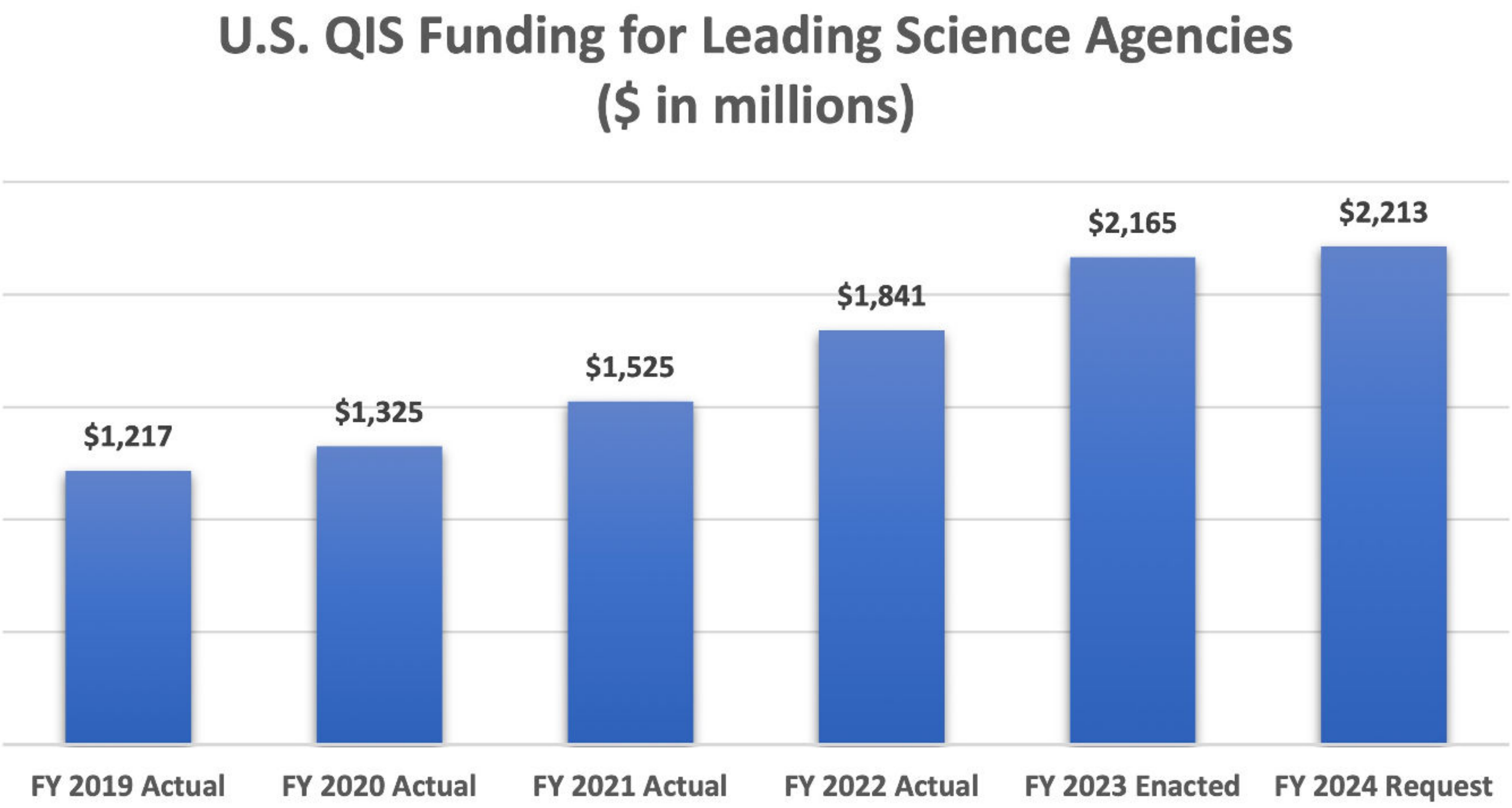
(2) invest in fundamental Federal quantum information science and technology research, development, demonstration, and other activities to achieve the goals established under paragraph (1);

(3) invest in activities to develop a quantum information science and technology workforce pipeline;

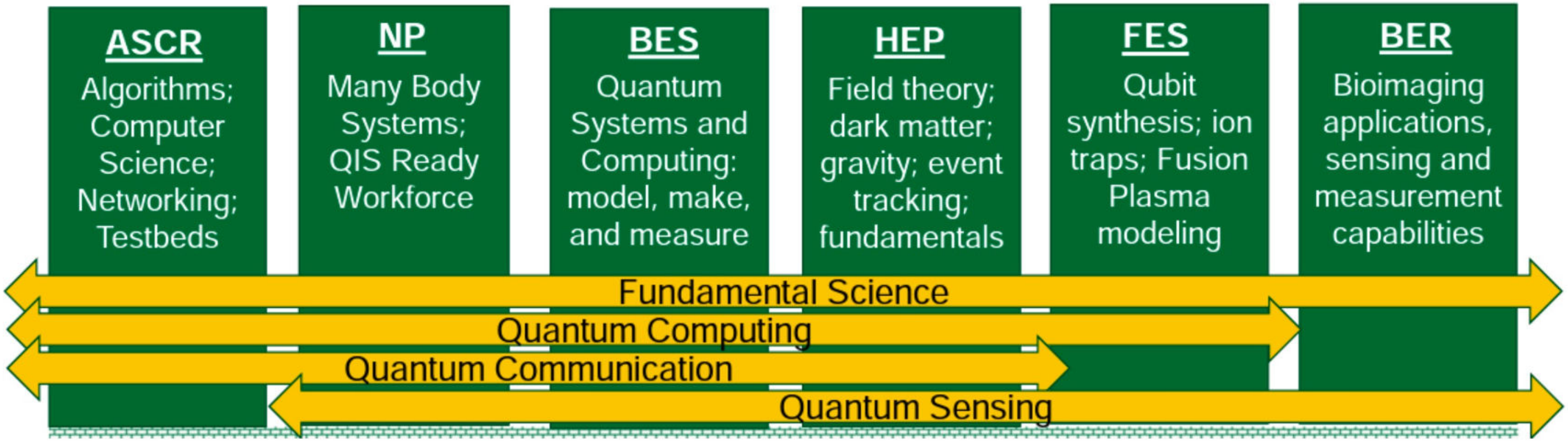
(4) provide for interagency planning and coordination of Federal quantum information science and technology research, development, demonstration, standards engagement, and other activities under the Program;

(5) partner with industry and universities to leverage knowledge and resources; and

(6) leverage existing Federal investments efficiently to advance Program goals and priorities established under paragraph (1).



Lewis-Burke Associates, LLC. **2023 Landscape of Federal Quantum Information Science.** May 2023.



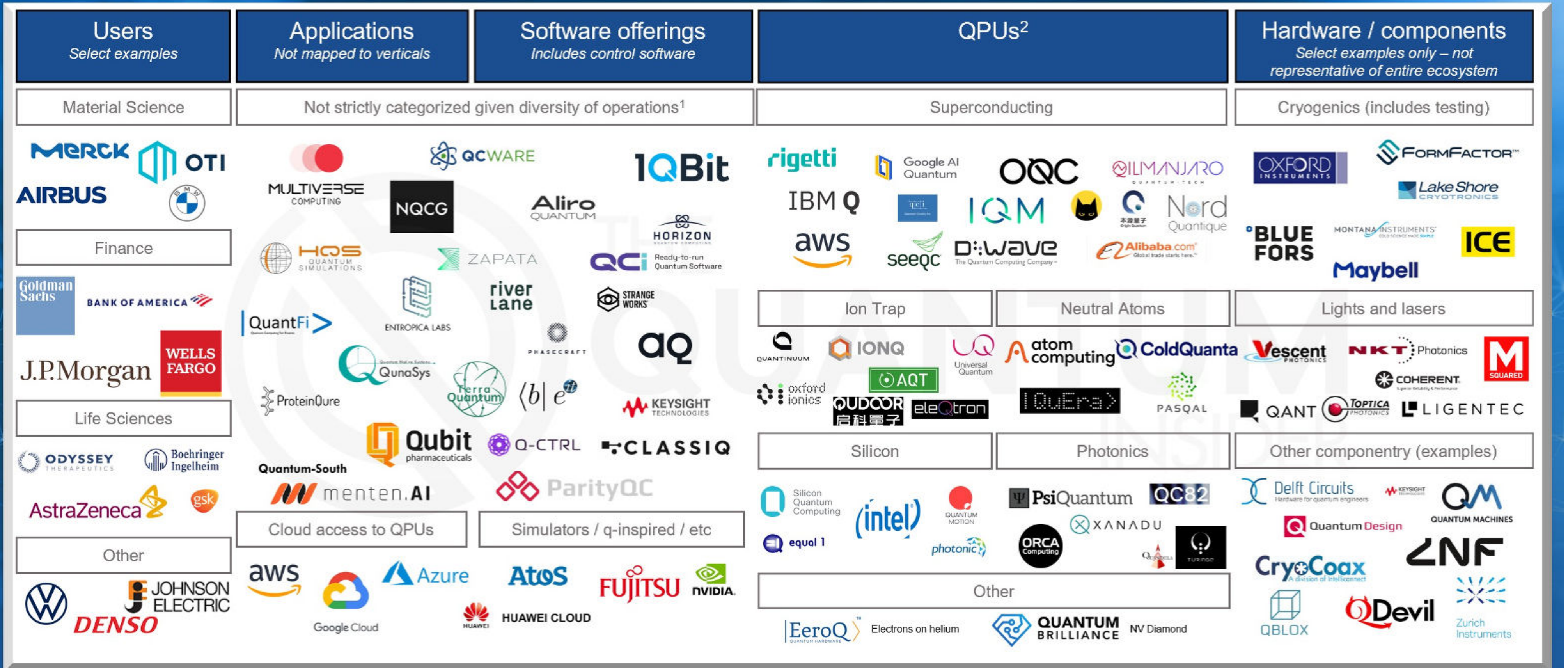
Source: DOE Office of Science

Lewis-Burke Associates, LLC. **2023 Landscape of Federal Quantum Information Science.** May 2023.

THE QUANTUM INSIDER

Quantum Computing Market Map

Non exhaustive and in no particular order. Excludes details on control systems, assembly languages, circuit design, etc.

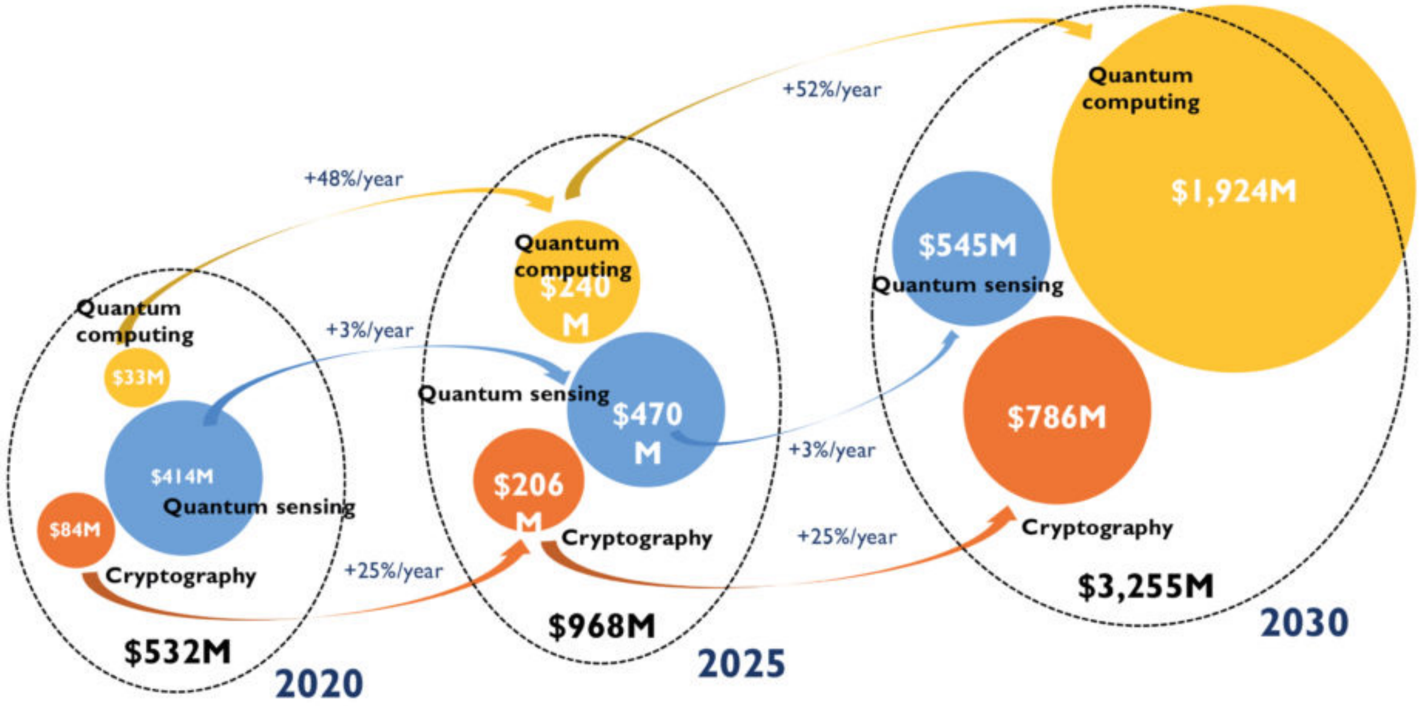


¹ Software offerings can be further classified into SDKs, firmware / enablers, algorithms / applications, simulators etc. but many companies are offering a mixture across the stack

² Many QPU providers are offering full stack services (e.g. Pasqal acquired Qu&Co, Quantinuum was originally CQC prior to merger with HQS, etc.

2020 – 2025 – 2030 quantum technologies forecast

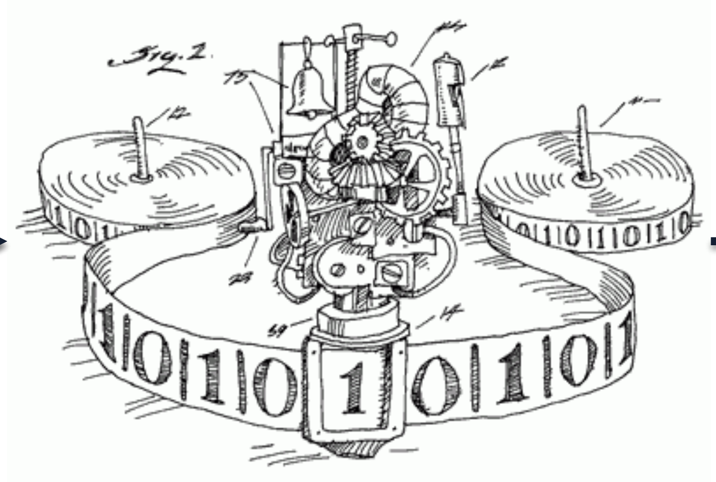
(Source: Quantum Technologies report, Yole Développement, 2020)



Principios

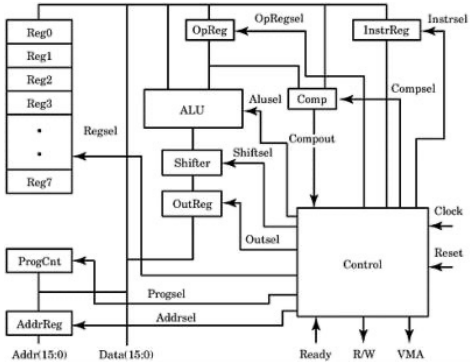
Computación

45 = $(101101)_2$



"Above freezing"

Ingeniería Elecrónica



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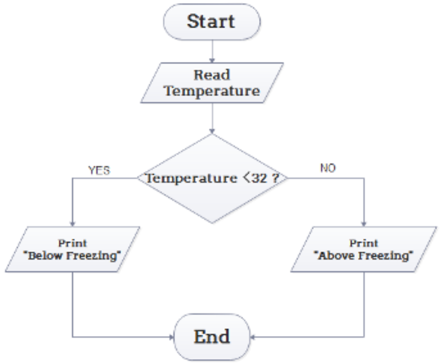
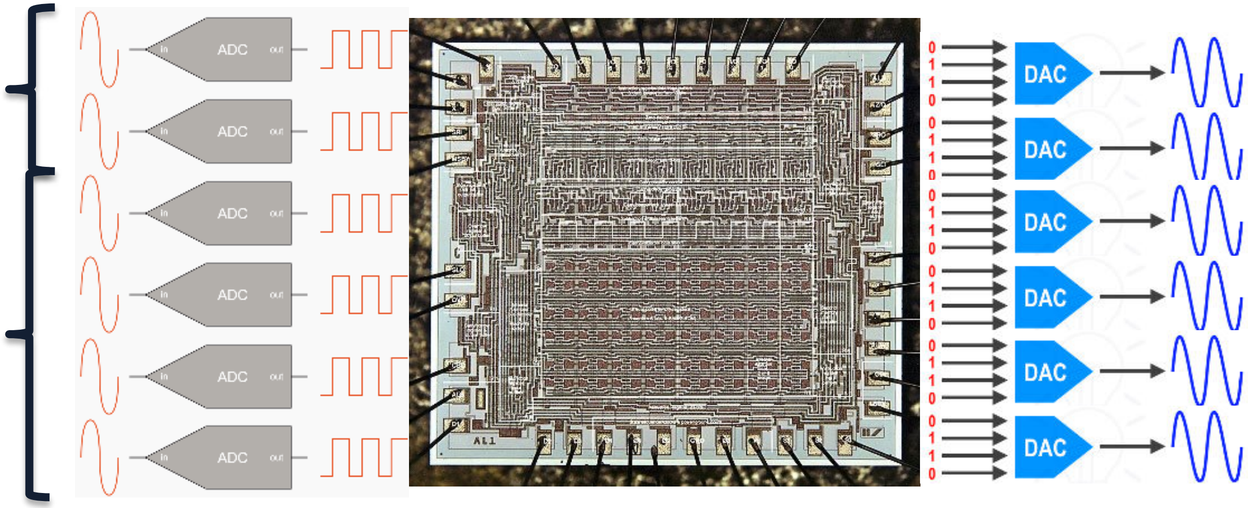
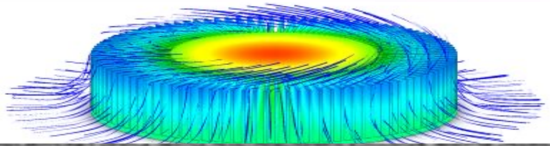
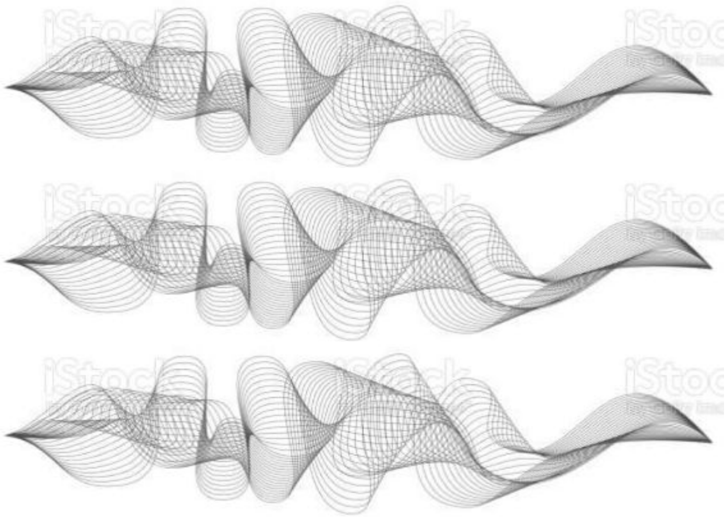
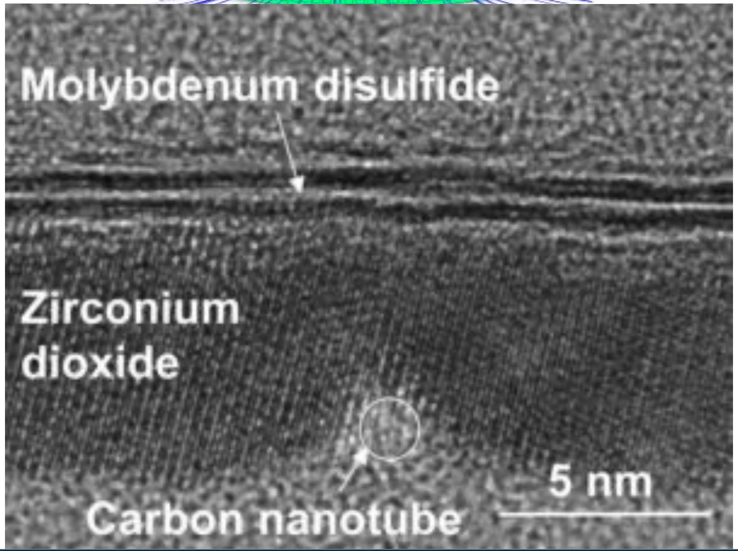


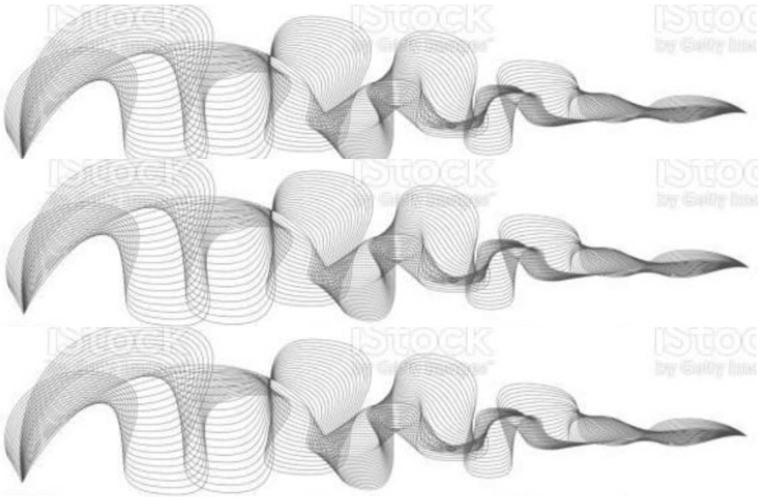


Física






Molybdenum disulfide
Zirconium dioxide
Carbon nanotube
5 nm



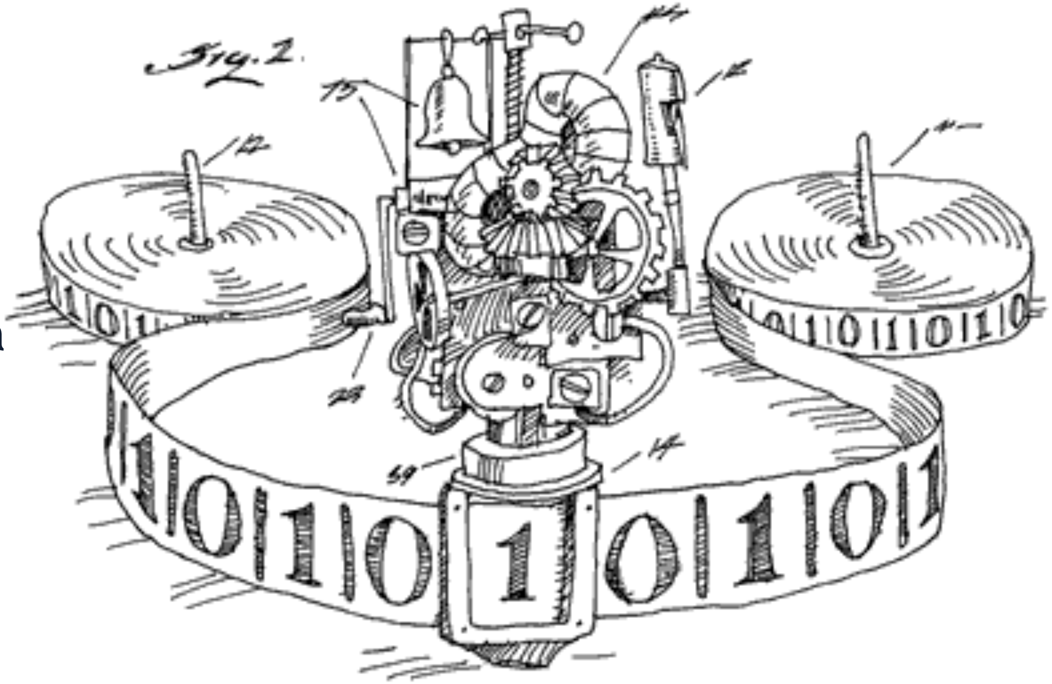
La computación es un conjunto de abstracciones procedurales

Estado finito

Terminación de programa

Entradas

Salidas



Estado único

Determinismo

Lectura no destructiva

Copiabilidad

Coherencia

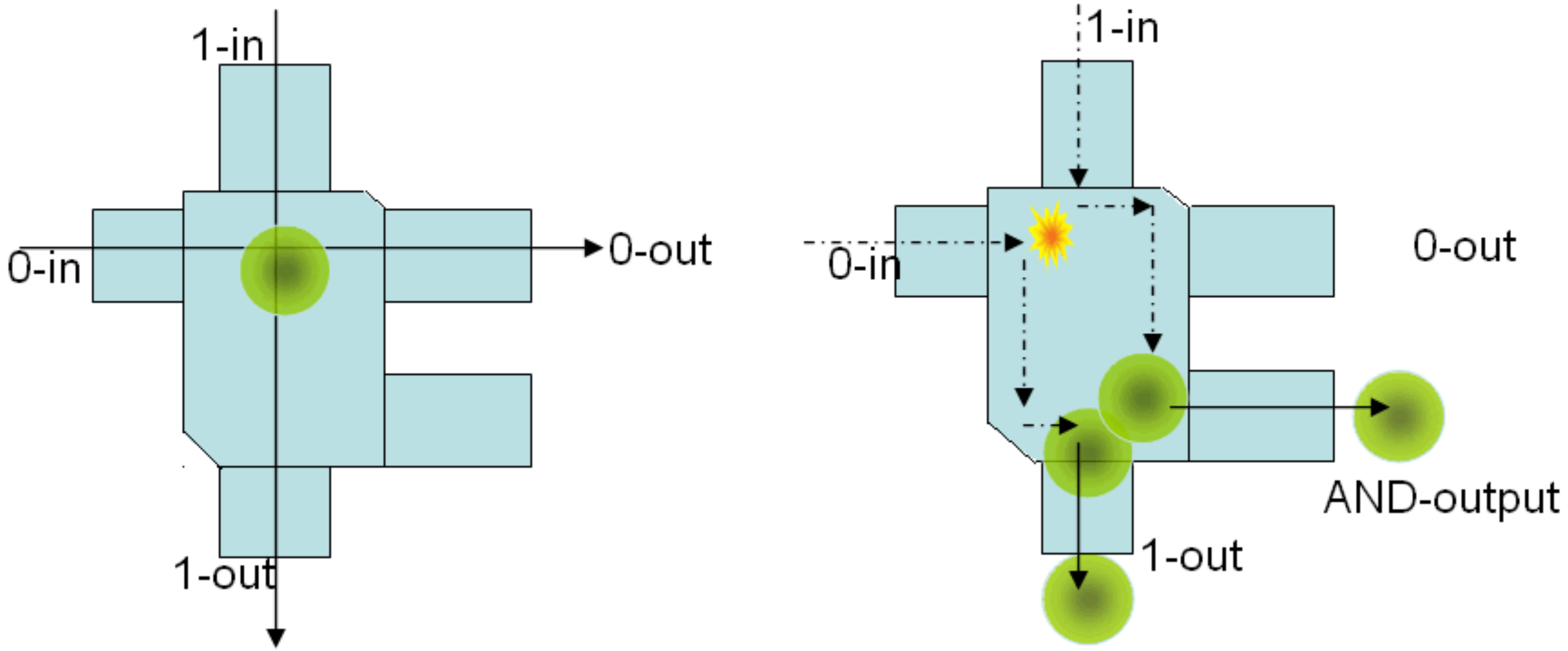
Tolerancia a ruido

Irreversibilidad

Localidad

Las Máquinas de Turing son disposivos Newtonianos!

Cómputo con bolas de billar

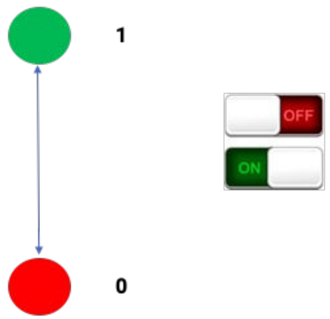


Durand-Lose, J., 2002. Computing inside the billiard ball model. *Collision-based computing*, pp.135-160.

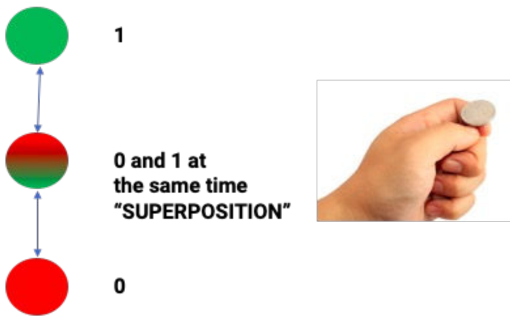
Bits cuánticos (qubits)

BITS vs QBITS

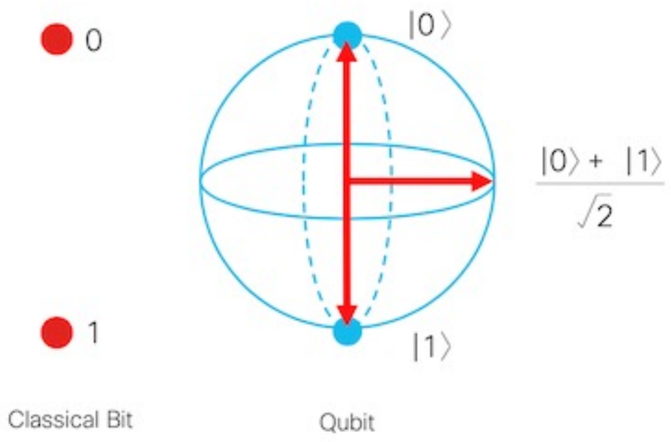
Classical Computer – Operations on BITS



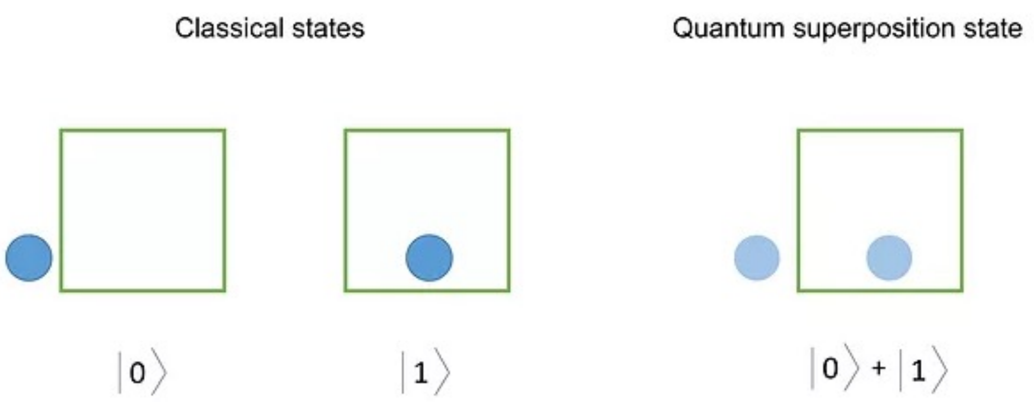
Quantum Computer – Operations on Quantum BITS

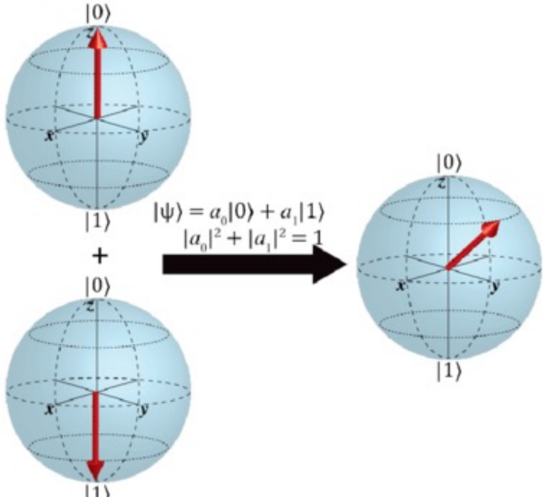


Quibits can take same value simultaneously. This characteristic expands the possibility of parallel calculations



Superposición e interferencia

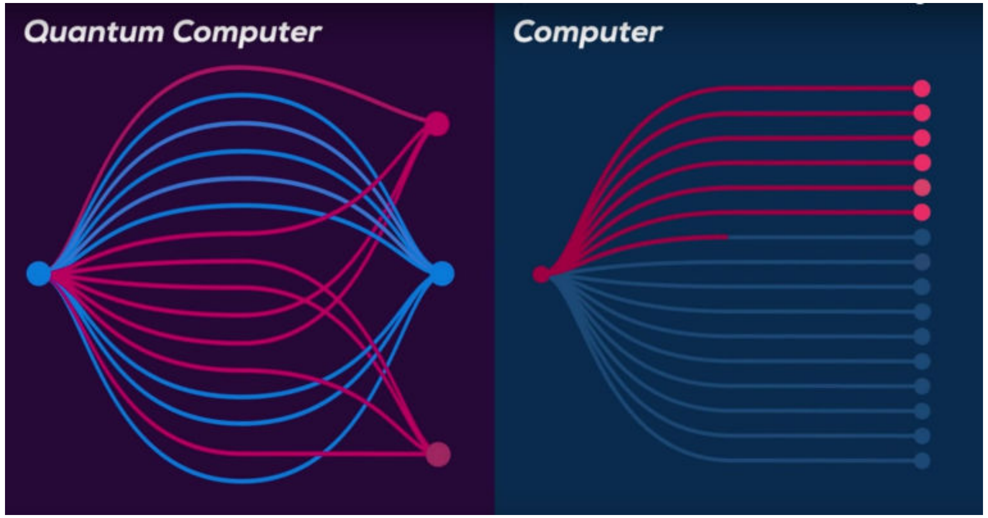




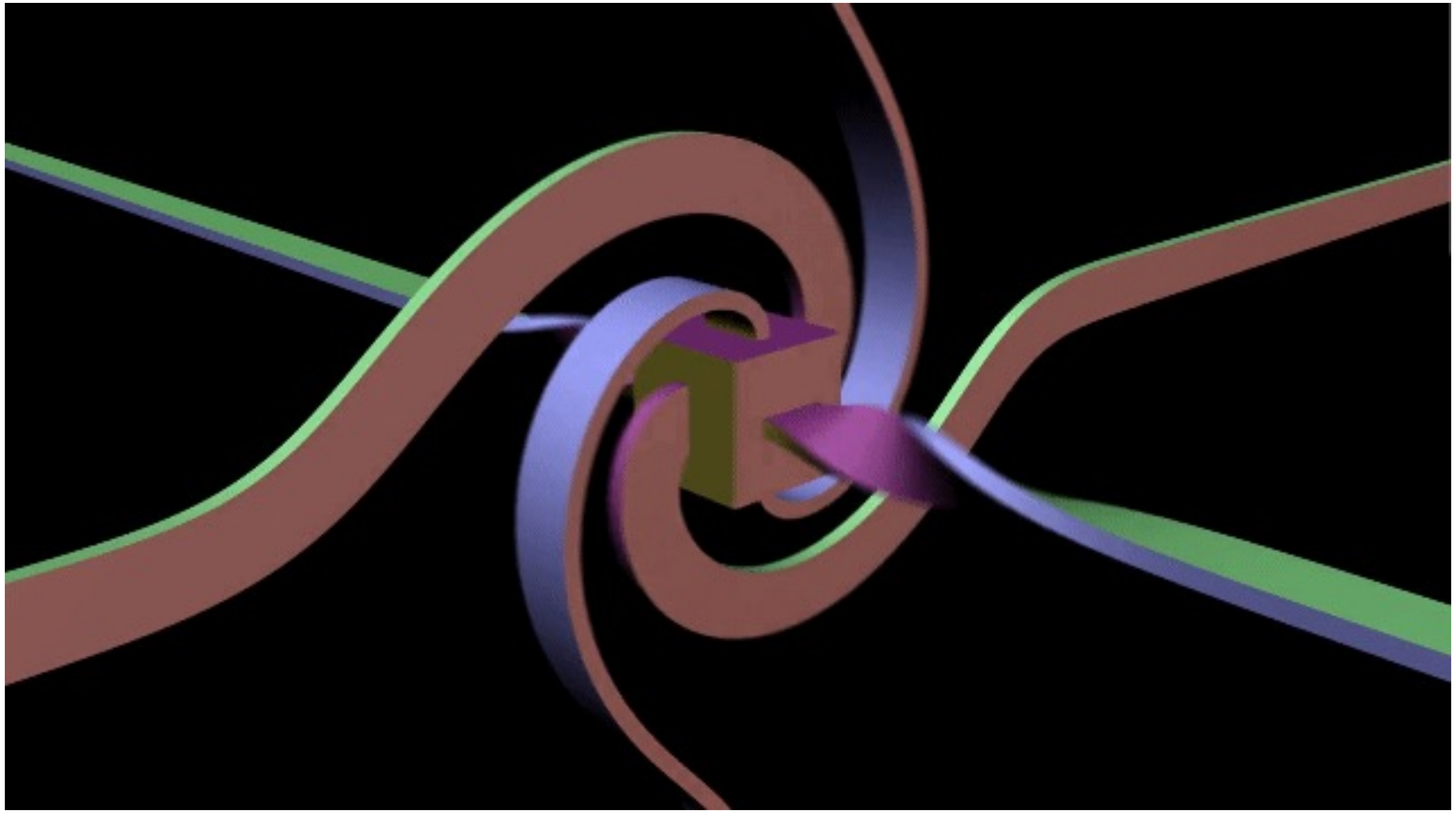
La habilidad de mantener multiples estados de información instantáneamente

El reto: medir destruye la superposición

La solución: interferencia constructiva y destructiva



Estados cuánticos = spinors con álgebras de Clifford

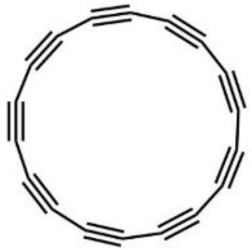


https://arxiv.org/abs/2003.05089

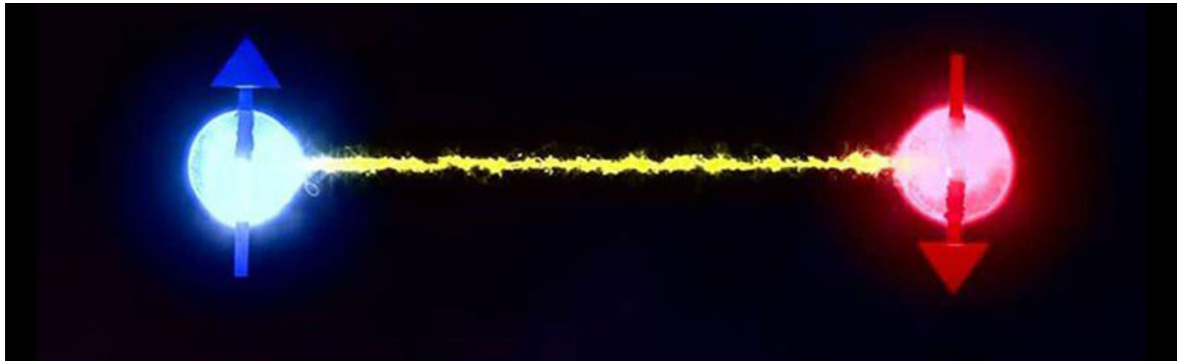
Simular estados cuánticos a escala es infectible en una computadora clásica

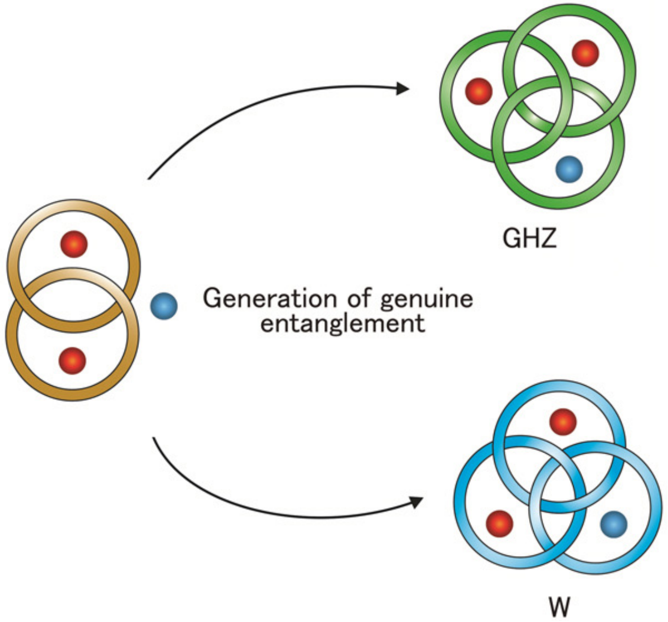
Qubits	Classical bits	Comparison
1	2	Binary contingency table
15	32768	Physical HDD sector
90	1.24×10^{27}	Atoms in an apple
186	1.21×10^{56}	Atoms in the solar system
267	3.28×10^{80}	Elementary particles in the observable universe

Largest exact quantum calculation of quantum system to date: C18
https://arxiv.org/abs/2207.03711
https://www.science.org/doi/10.1126/science.aay1914



Entanglement



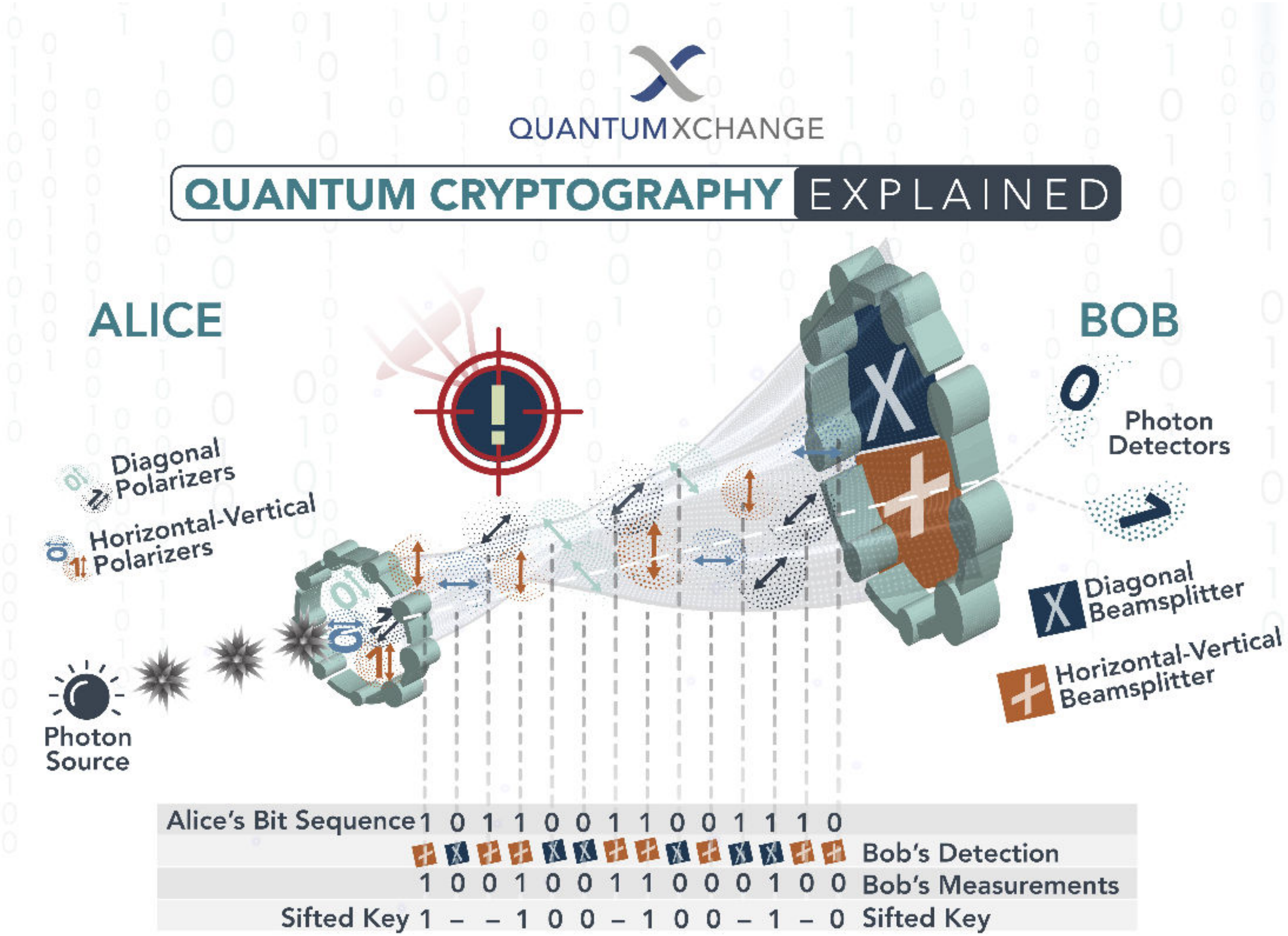


La propiedad de un sistema cuántico de matener un solo estado coherente y correlacionado a pesar de separación física de sub-sistemas

Einstein's "spooky action at a distance"

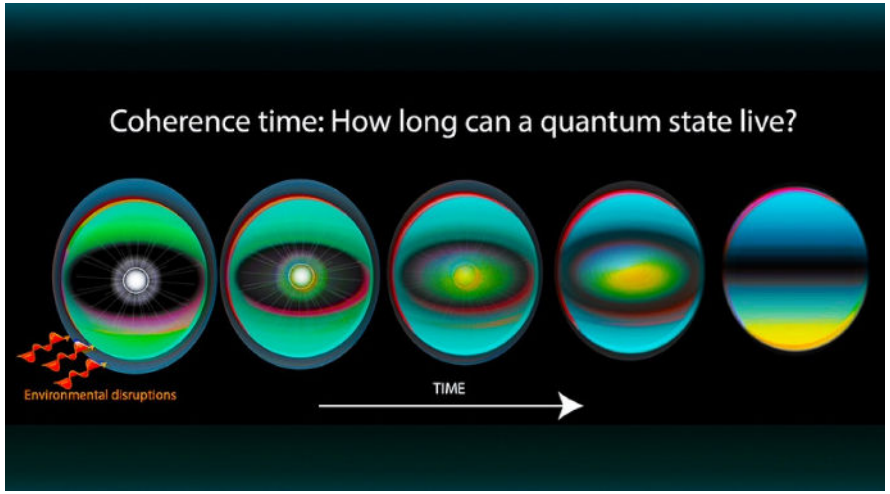
Ventaja: codificar más información por qubit comparado a bits clásicos

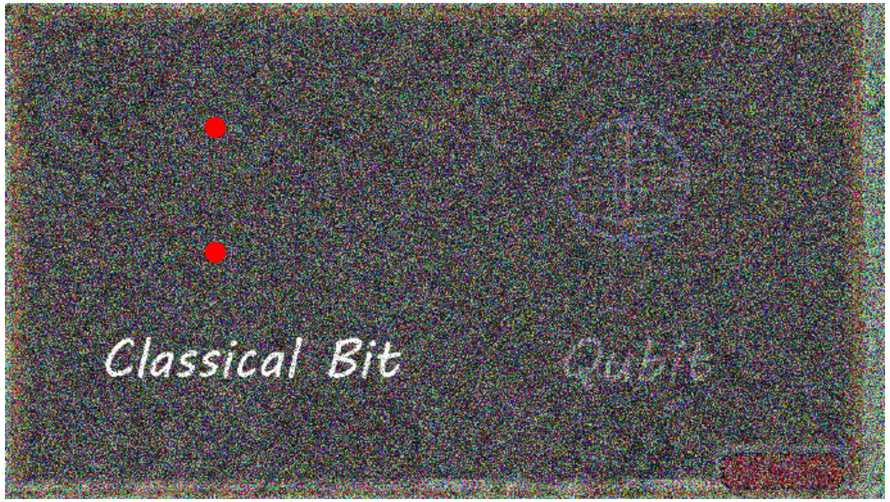
- Quantum communication
- Superdense coding
- Quantum cryptography
- Quantum machine learning



E.g., https://www.idquantique.com/quantum-safe-security/applications/banking-solutions/

Decoherencia





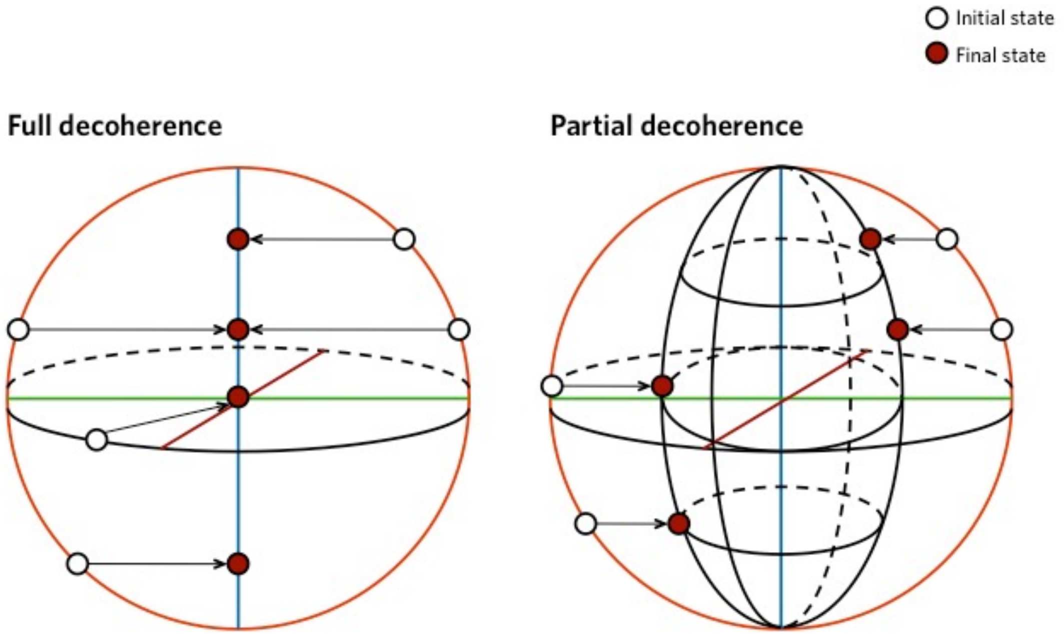
La propiedad de sistemas cuánticos de regresar a estados preferenciales al interactuar con el ambiente

La decoherencia es una barrera científica y técnica fundamental en la capacidad de implementar dispositivos físicos capaces de cómputo cuántico

Ruido cuántico: mecánico, térmico, 'shot', dephasing, cross-talk

La decoherencia causa errores irreversibles en estados cuánticos, y es el factor limitante más importante de esta tecnología

La evolución de un Sistema cuántico está dada por una equación Fokker'Planck en *ict!*



La probabilidad cambia constantemente en quantum

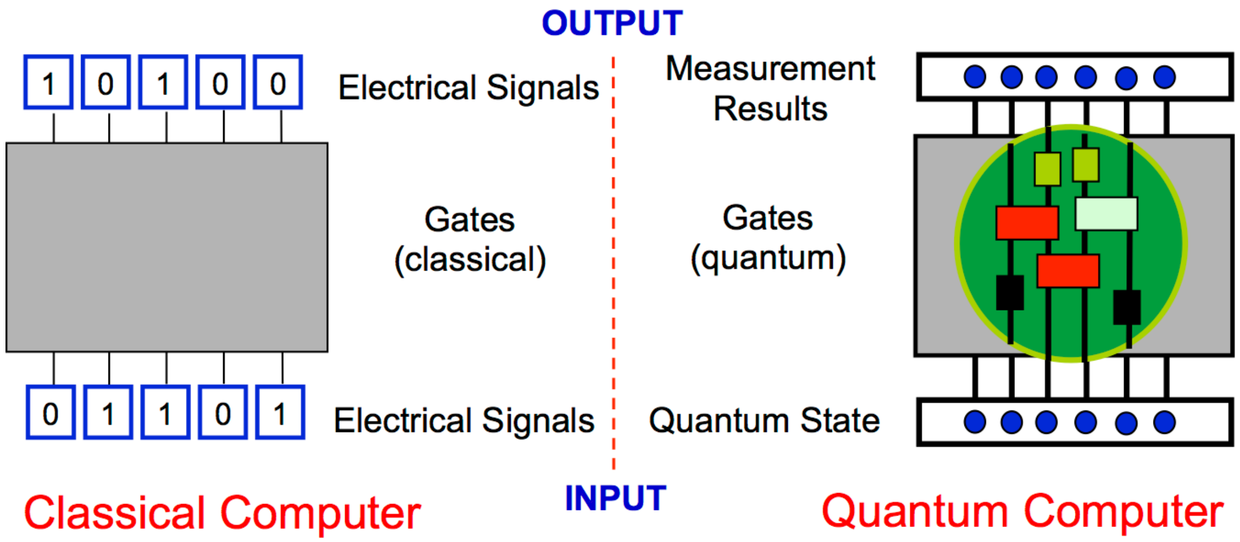
$$i\hbar\partial_t\psi(x,t) = -\frac{\hbar^2}{2m}\partial_x^2\psi(x,t) + V(x,t)\psi(x,t)$$

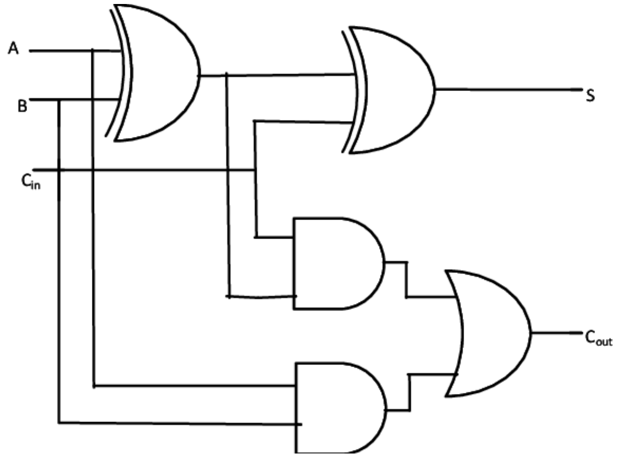
$$\partial_t f(v,t) = -\partial_v[\mu(v,t)f(v,t)] + \partial_v^2[D(v,t)f(v,t)]$$

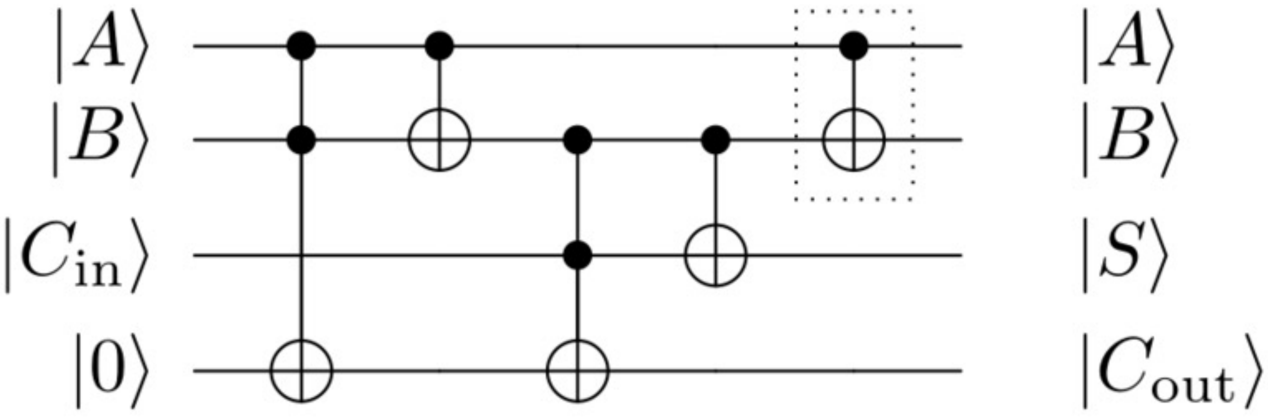
$$\partial_t f(x,t) = -\partial_x[\mu(x,t)f(x,t)] + \partial_x^2[D(x,t)f(x,t)]$$

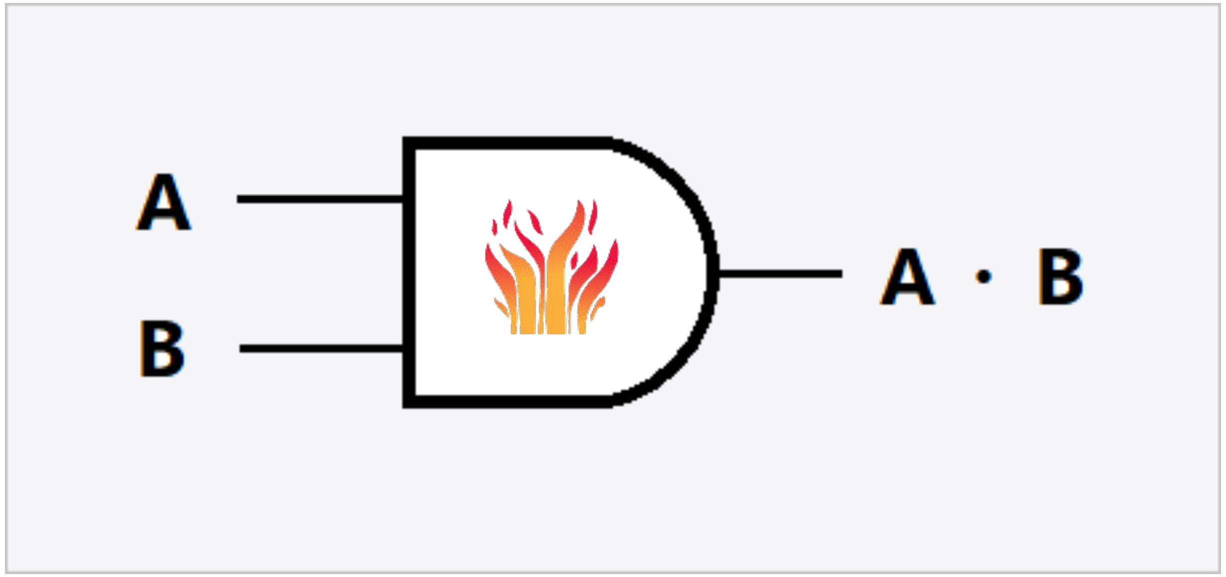
$$\partial_t\psi(x,t) = \frac{i}{\hbar}\frac{\hbar^2}{2m}\partial_x^2\psi(x,t) - \frac{i}{\hbar}V(x,t)\psi(x,t)$$

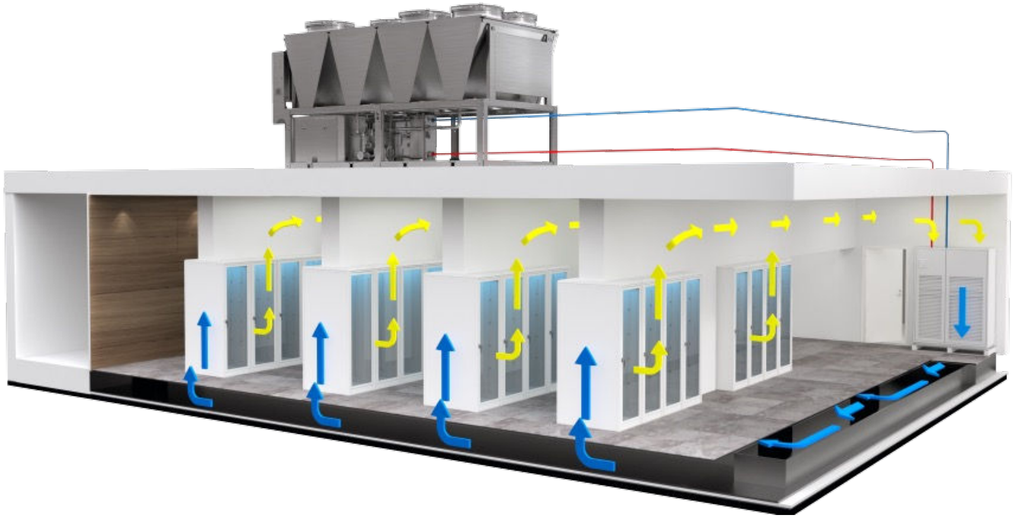
No hay un modo *idle* de procesador en quantum!


OUTPUT
1 0 1 0 0
Electrical Signals
Gates
(classical)
0 1 1 0 1
Electrical Signals
Classical Computer
INPUT
Measurement
Results
Gates
(quantum)
Quantum State
Quantum Computer

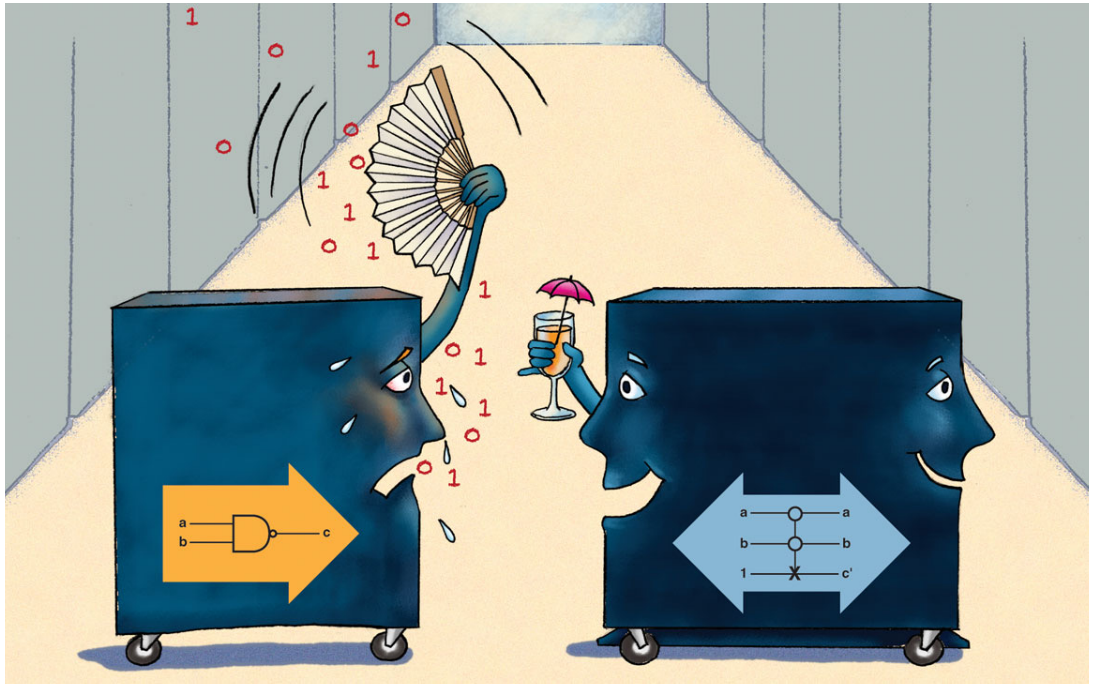

A
B
C_{in}
S
C_{out}


$|A\rangle$
$|B\rangle$
$|C_{\text{in}}\rangle$
$|0\rangle$
$|A\rangle$
$|B\rangle$
$|S\rangle$
$|C_{\text{out}}\rangle$





Landauer, R. (1961). **Irreversibility and heat generation in the computing process**. *IBM Journal of Research and Development*, *5*(3), 183-191.



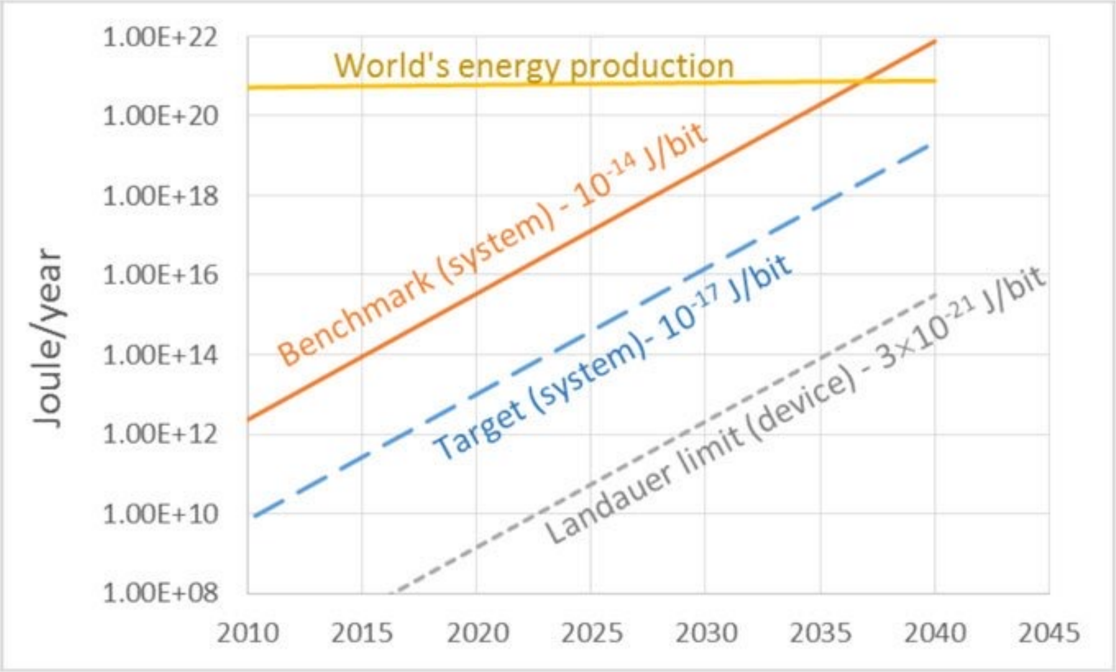
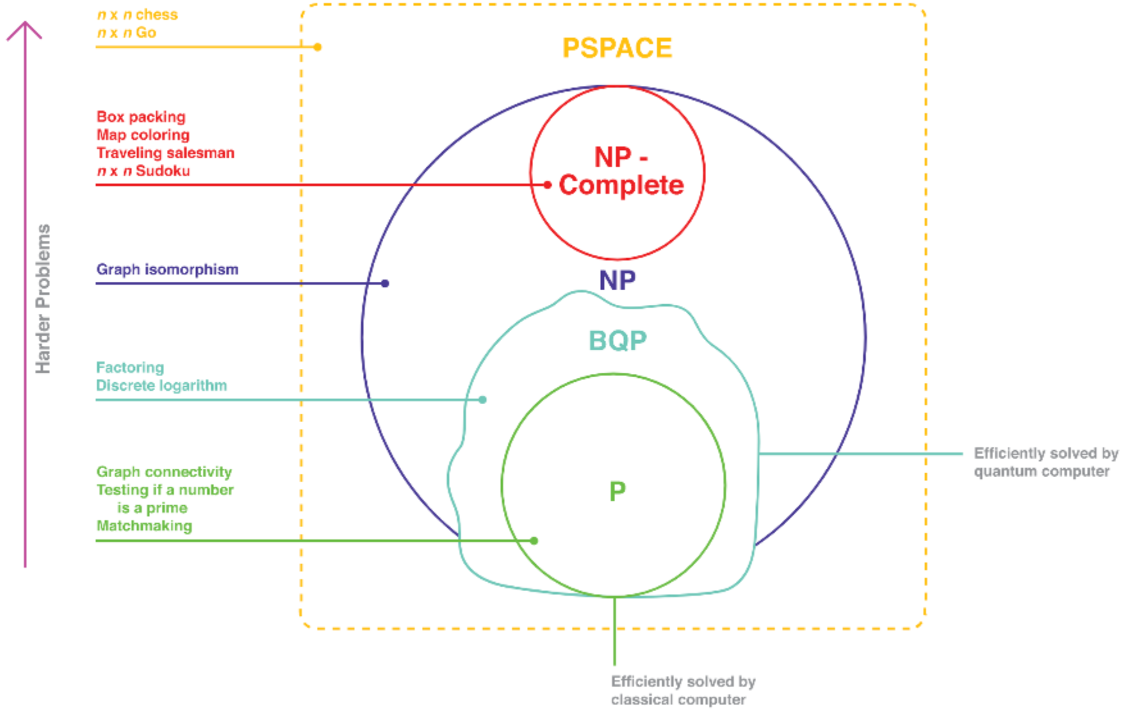


Fig. A8. Total energy of computing.

https://www.americanscientist.org/article/computers-that-can-run-backwards

Drechsler, R., & Wille, R. (2012). **Reversible circuits: Recent accomplishments and future challenges for an emerging technology.** In *Progress in VLSI Design and Test* (pp. 383-392). Springer, Berlin, Heidelberg.

Quantum puede resolver ciertos problemas eficientemente



Type of scaling	Time to solve problem				
Classical algorithm with exponential runtime	10 secs	2 mins	330 years	3300 years	Age of the universe
Quantum algorithm with polynomial runtime	1 min	2 mins	10 mins	11 mins	~24 mins

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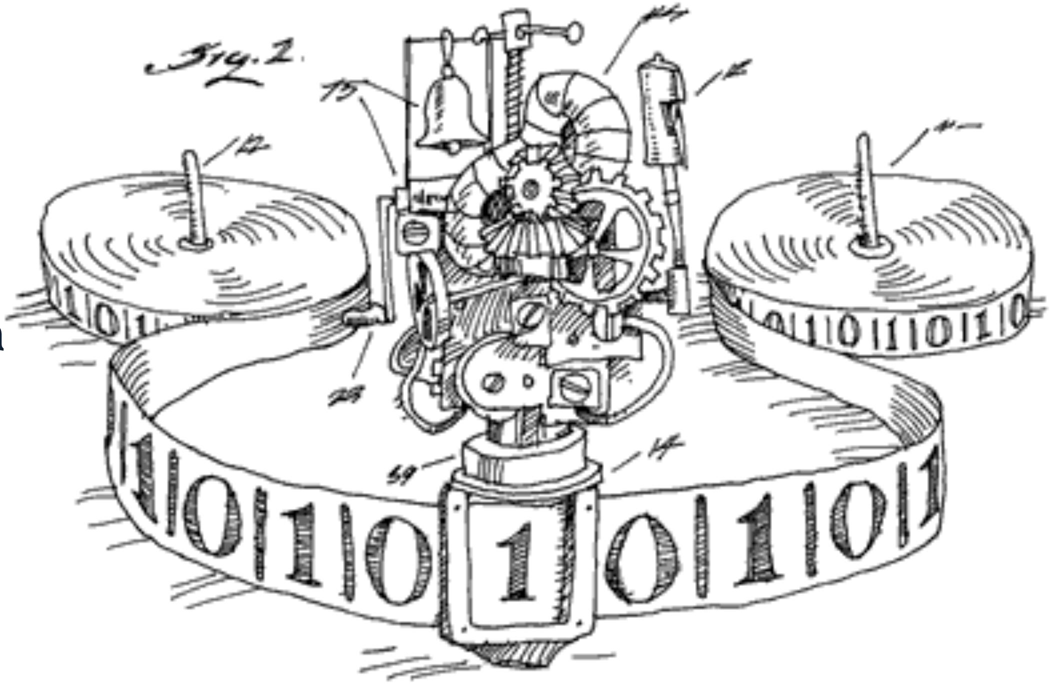
La computación es un conjunto de abstracciones procedurales

Estado finito

Terminación de programa

Entradas

Salidas



Simultaneidad de estados

Probabilidades complejas

Lectura destructiva

No clonación

Decoherencia

Noise sensitive

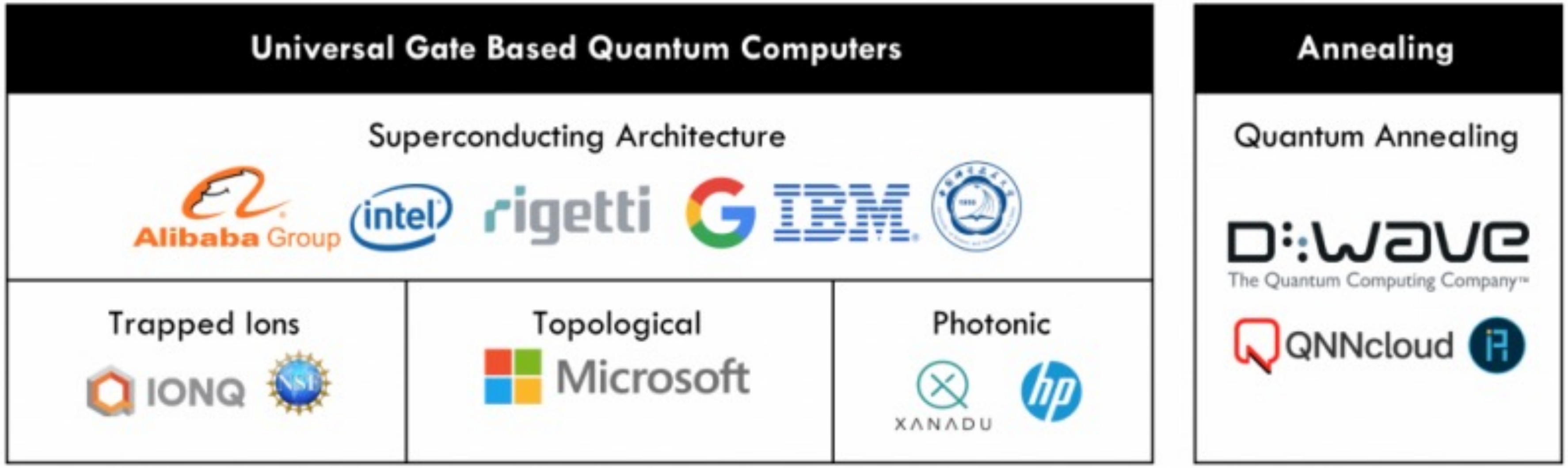
Reversibility

Non-locality

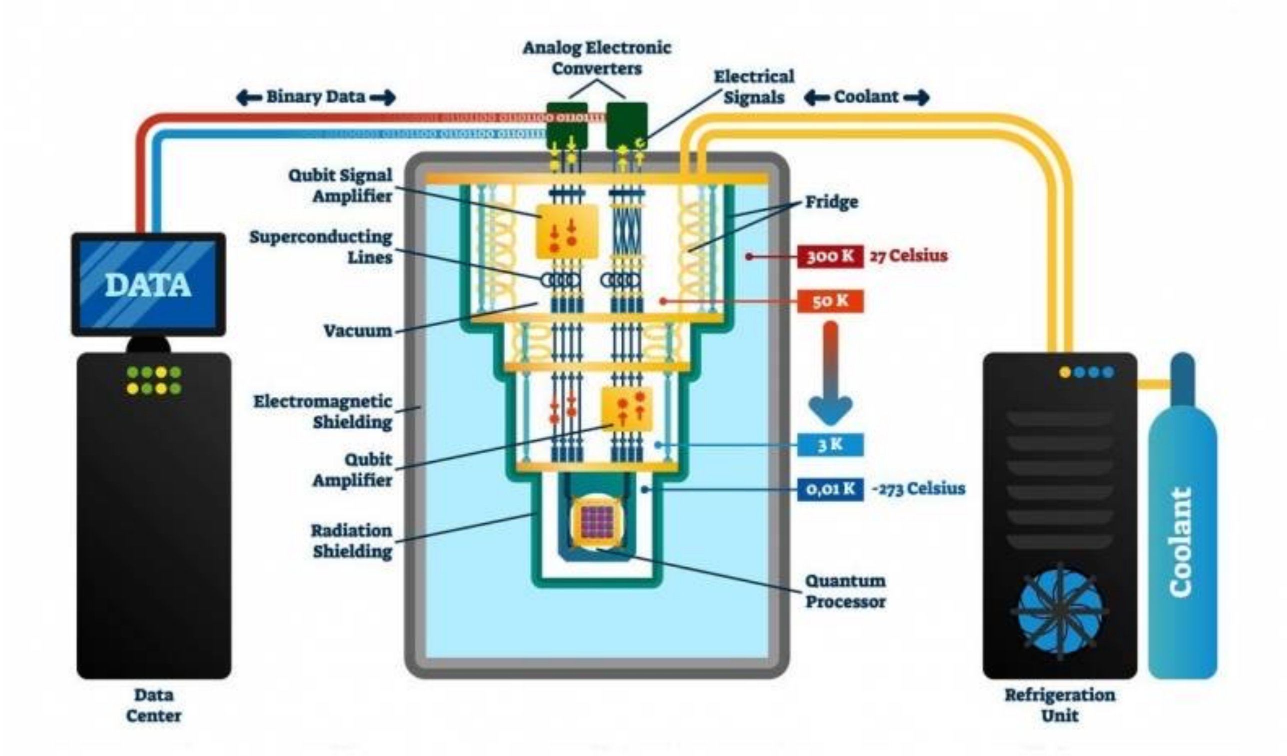
Quantum machines are different beasts!

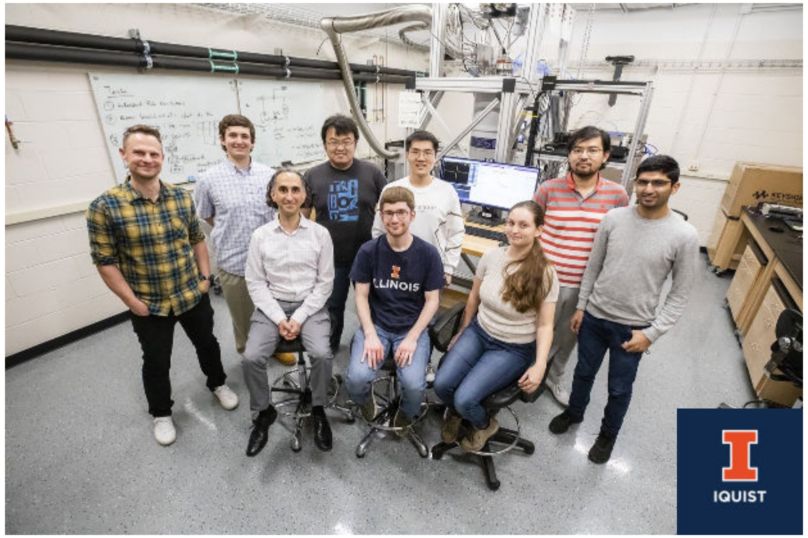
Sistemas

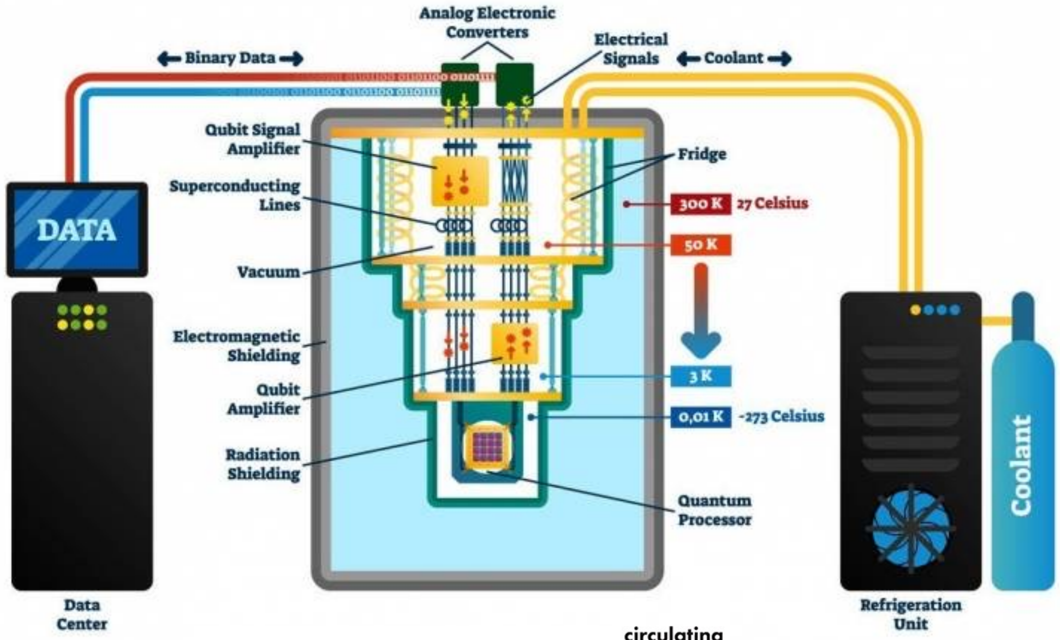
Múltiples sabores de hardware cuántico

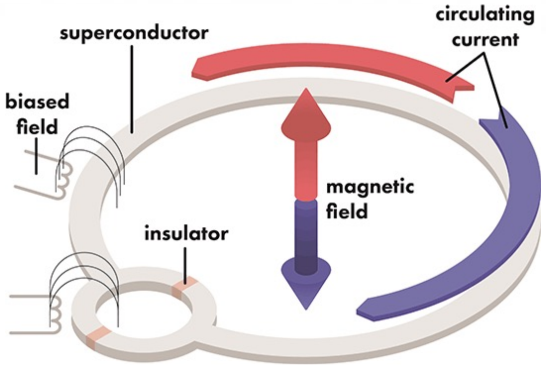


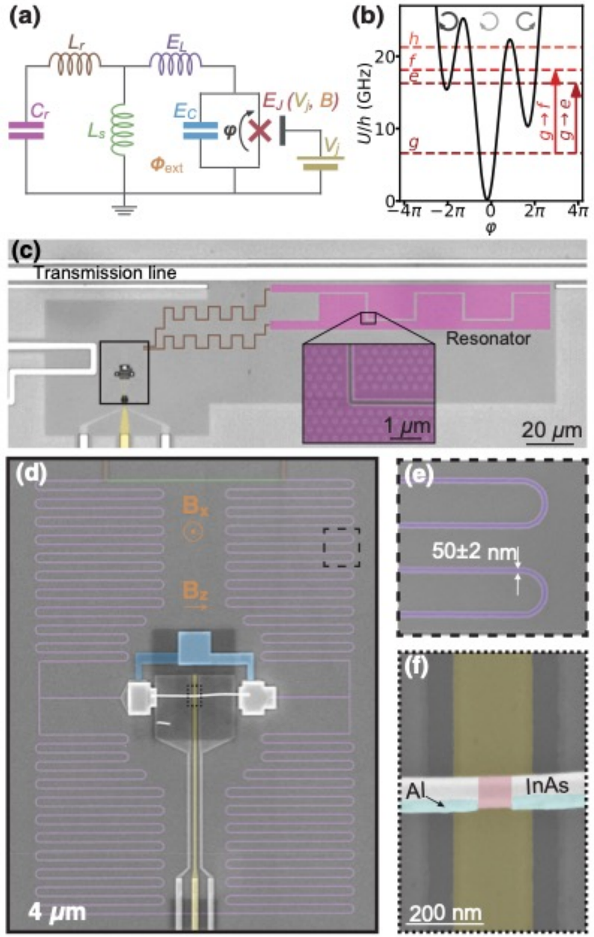
QC con Superconductores









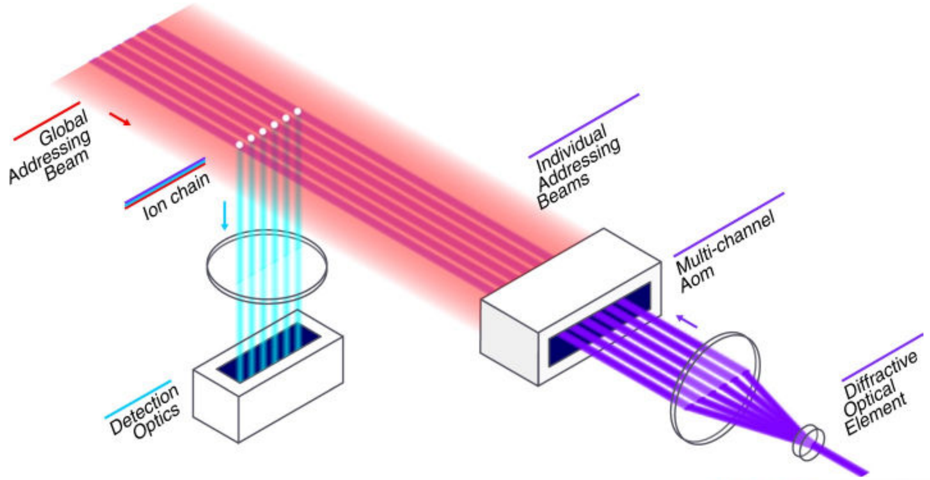


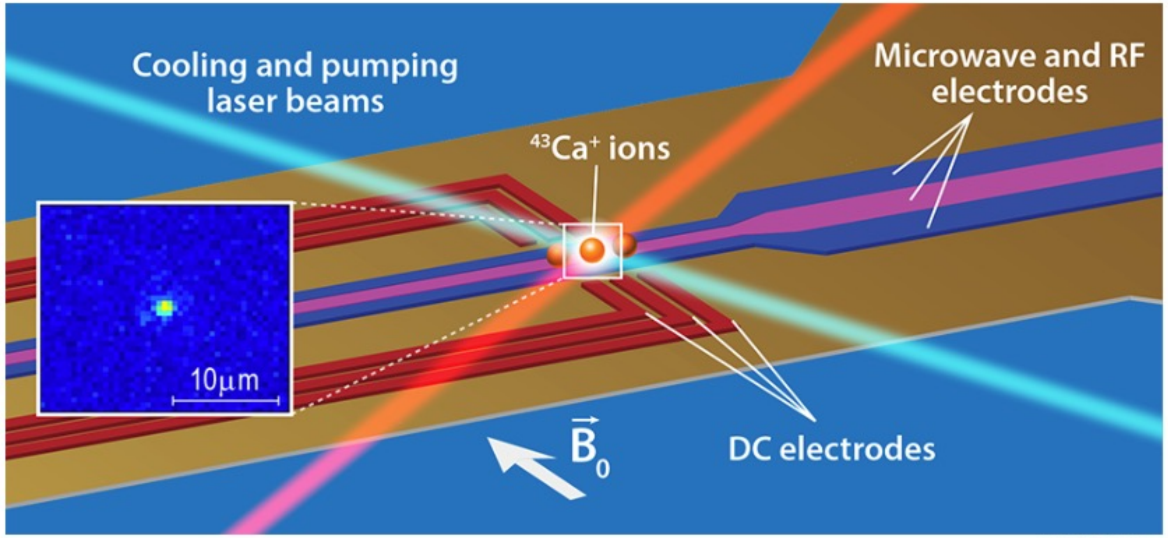
$$\hat{H} = \frac{2e^2}{C_r}\hat{n}_r^2 + \frac{1}{2}\frac{(\Phi_0/2\pi)^2}{(L_r+L_s)}\hat{\varphi}_r^2 - \frac{1}{2}\frac{(\Phi_0/2\pi)^2 L_s}{L_f\,(L_r+L_s)}\hat{\varphi}_r\hat{\varphi}_f + \hat{H}_f$$

$$\dot{\rho} = -\frac{i}{\hbar}[H,\rho] + \sum_{n,m=1}^{N^2-1} h_{nm}\left(A_n\rho A_m^\dagger - \frac{1}{2}\left\{A_m^\dagger A_n,\rho\right\}\right)$$

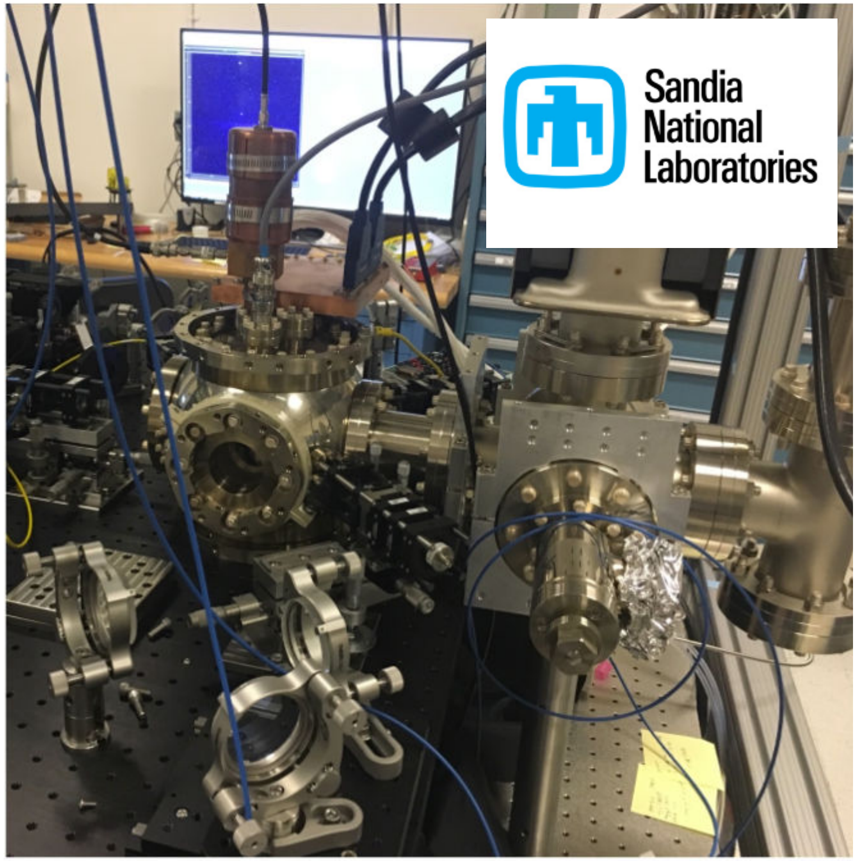
Pita-Vidal, M., Bargerbos, A., Yang, C.K., Van Woerkom, D.J., Pfaff, W., Haider, N., Krogstrup, P., Kouwenhoven, L.P., De Lange, G. and Kou, A., 2020. Gate-tunable field-compatible fluxonium. *Physical Review Applied*, *14*(6), p.064038.

Trampas de iones

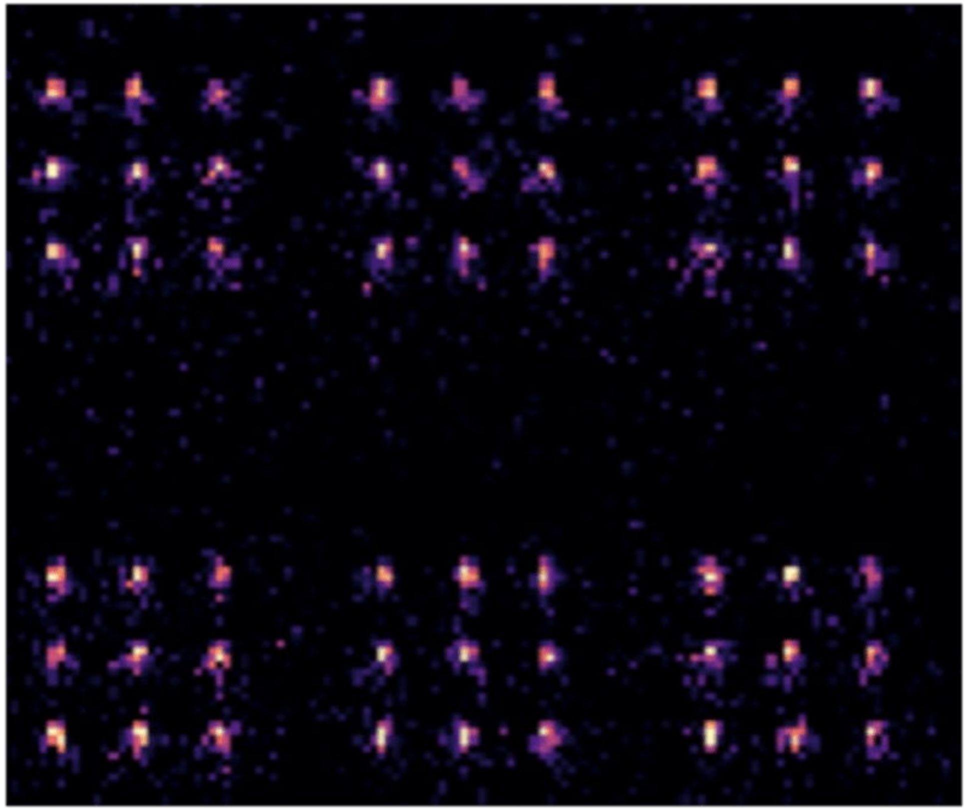


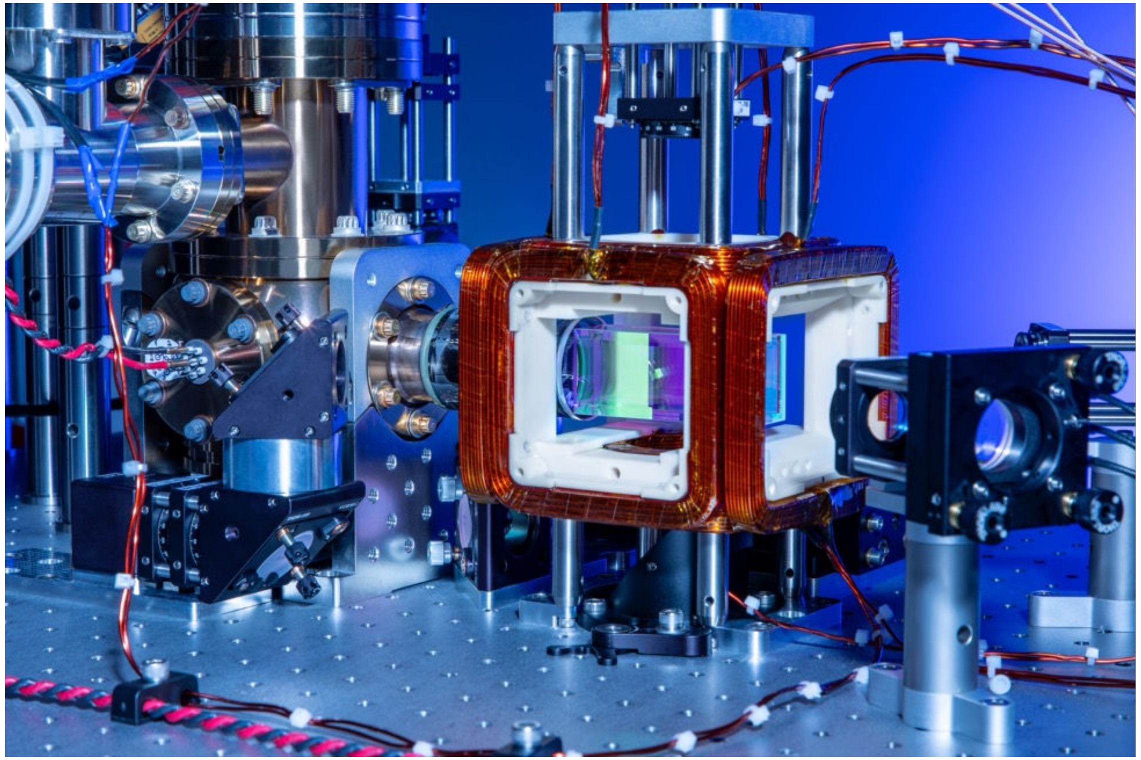


APS/Alan Stonebraker

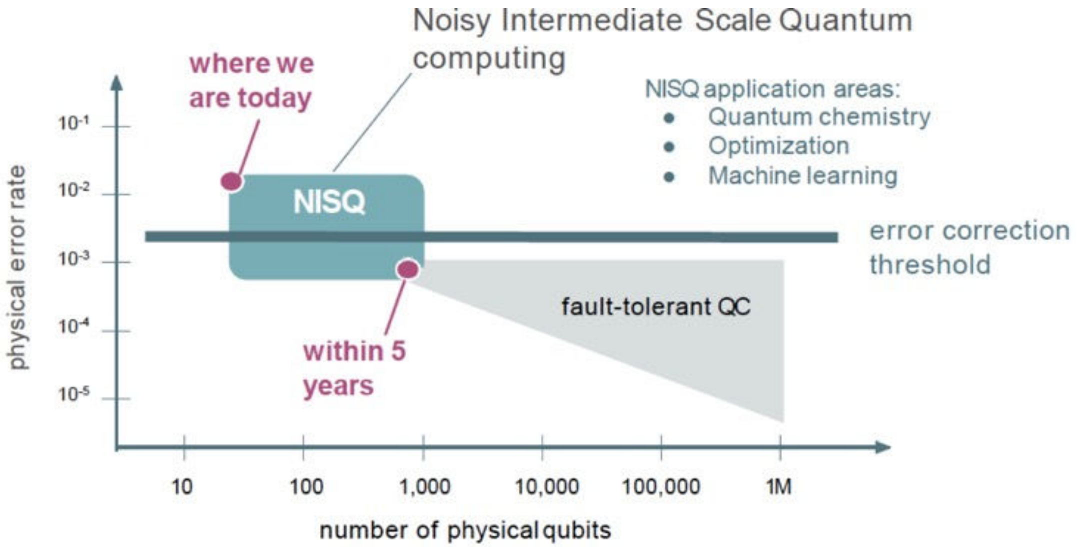


Átomos neutros/fríos





El hardware cuántico está en la infancia



"Quantum computing in the NISQ era and beyond" Preskill, 2018 https://arxiv.org/abs/1801.00862

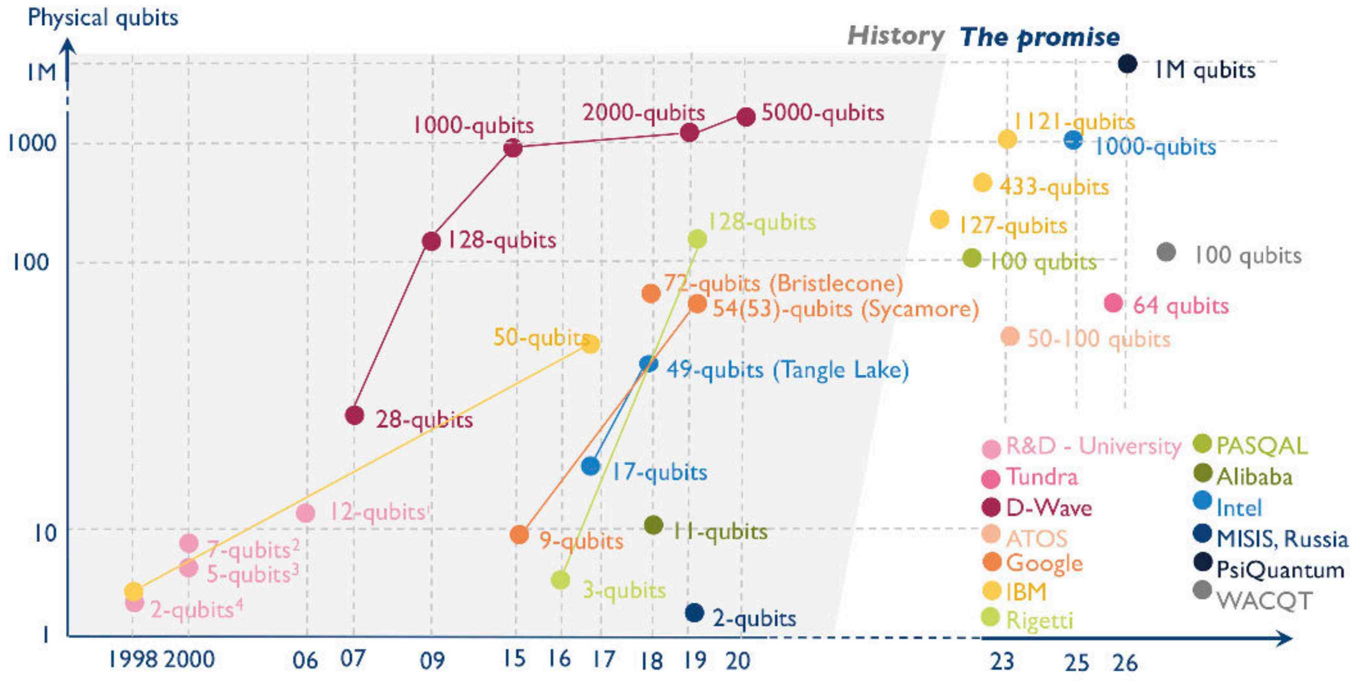
Quantum systems are moving from research into prototyping and, in some cases, early production systems

- Fundamental unknowns about entanglement and its implications for system scaling
- Single-gate errors still larger than ideal
- Hardware/software yet to standardize

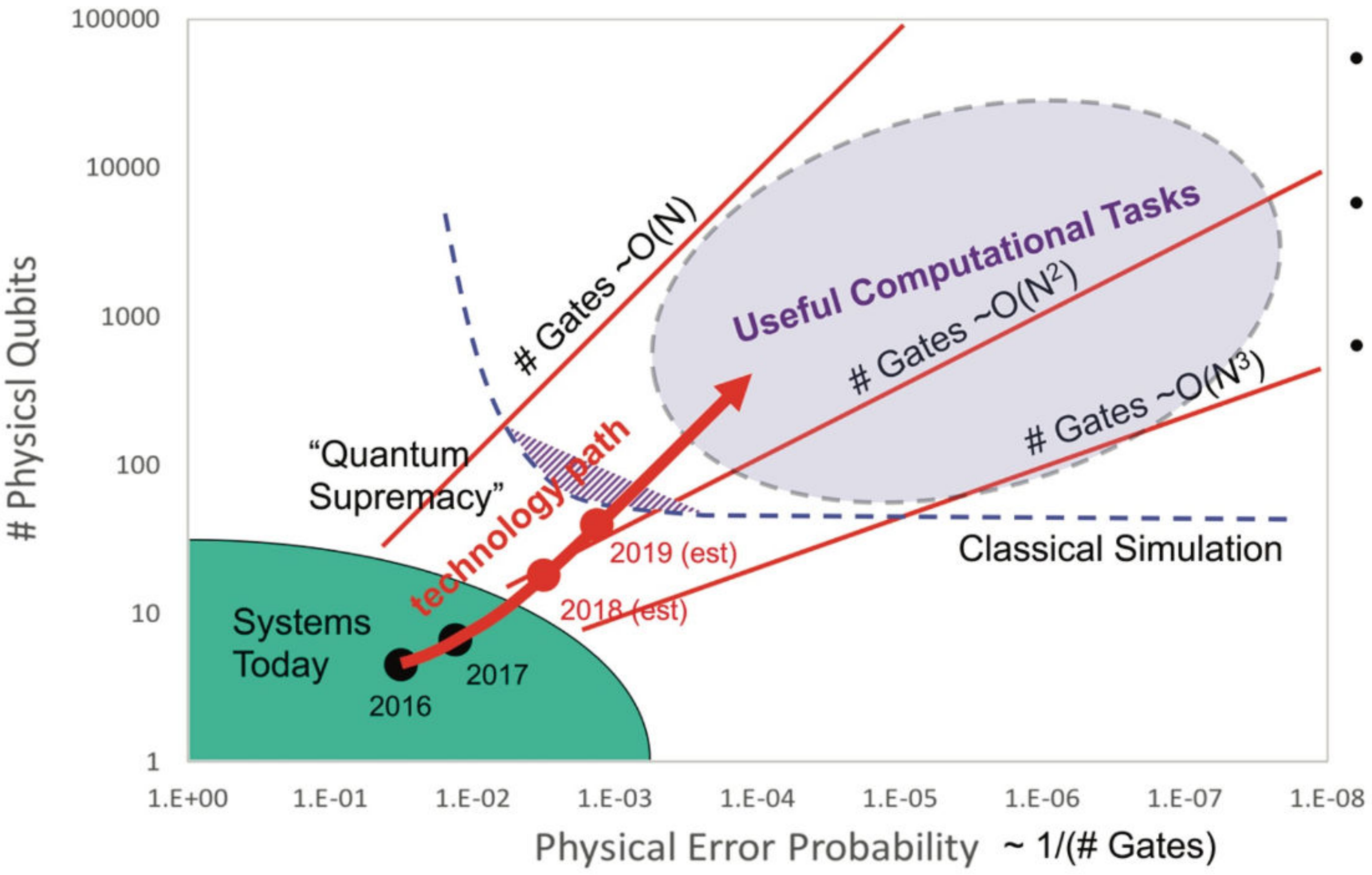
But: investment has moved from pre-competitive to competitive

1998-2026 Physical qubit roadmap for quantum computer

(Source: Quantum Technologies 2021 report, Yole Développement, 2021)

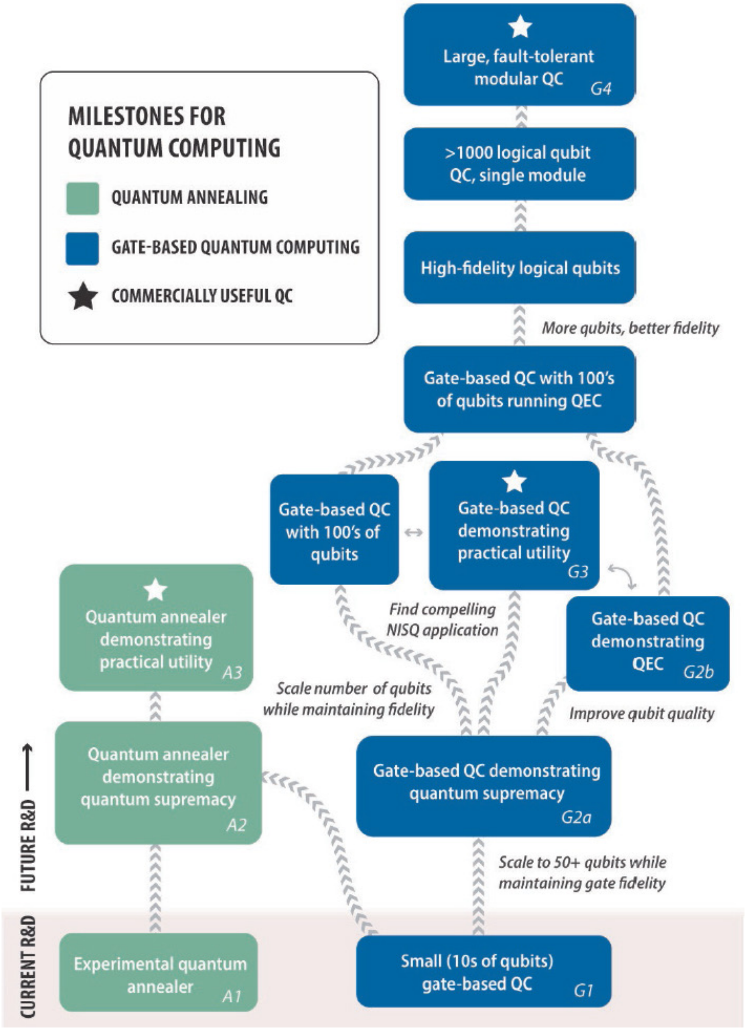


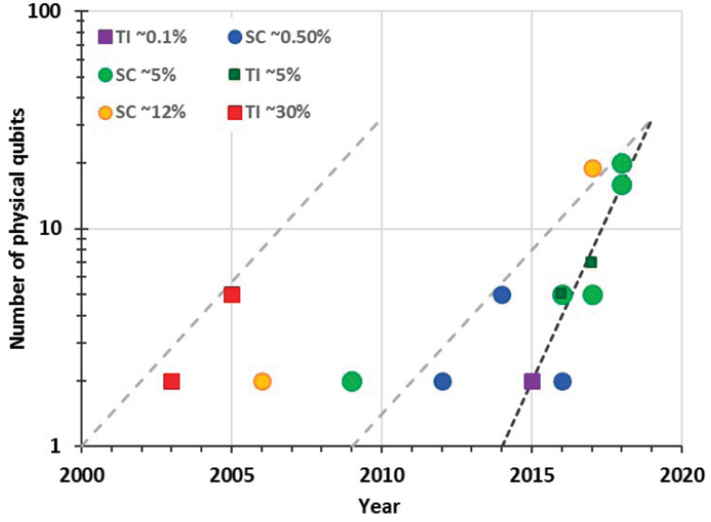
[1] (Institute for Quantum Computing, Perimeter Institute for Theoretical Physics, MIT)
[2] (Los Alamos National lab)
[3] (TU Munich)
[4] (Oxford University, IBM, UC Berkeley, Stanford, MIT)

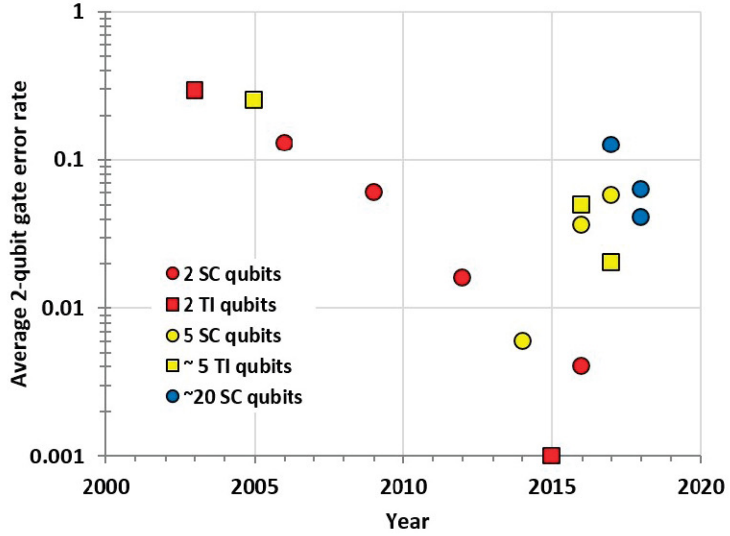


- First, reach a fault-tolerant qubit
- Then scale up in numbers
- Interesting computational tasks beyond classical simulation limit

Martonosi, M., & Roetteler, M. Next steps in quantum computing: computer science's role. arXiv preprint arXiv:1903.10541. 2019.







National Academies of Sciences, Engineering, and Medicine. *Quantum computing: progress and prospects*. National Academies Press. 2019.

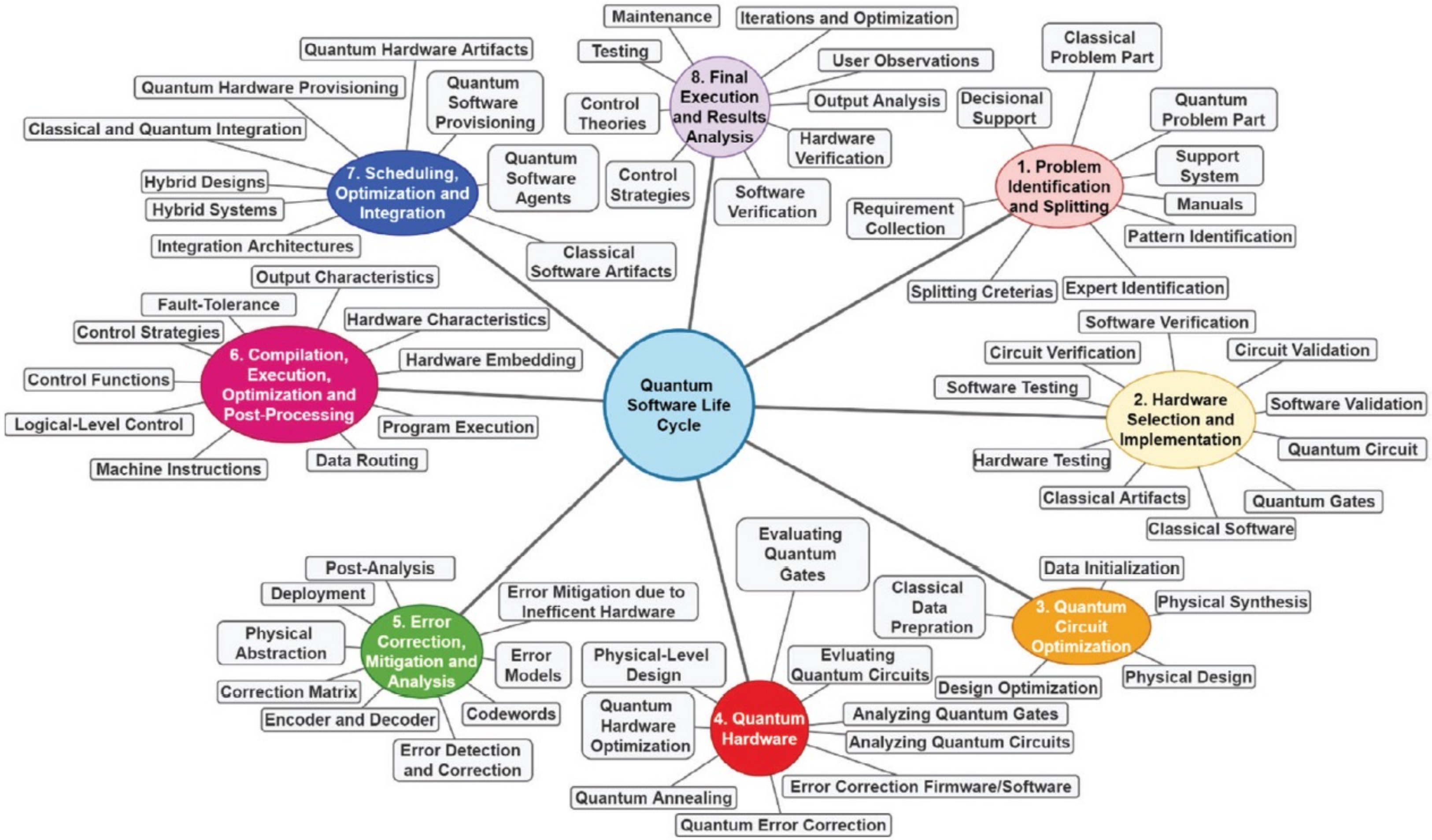


FIGURE 9 Quantum software life cycle and associated terminologies

Gill, S.S., Kumar, A., Singh, H., Singh, M., Kaur, K., Usman, M. and Buyya, R., 2022. Quantum computing: A taxonomy, systematic review and future directions. *Software: Practice and Experience*, *52*(1), pp.66-114

Aplicaciones

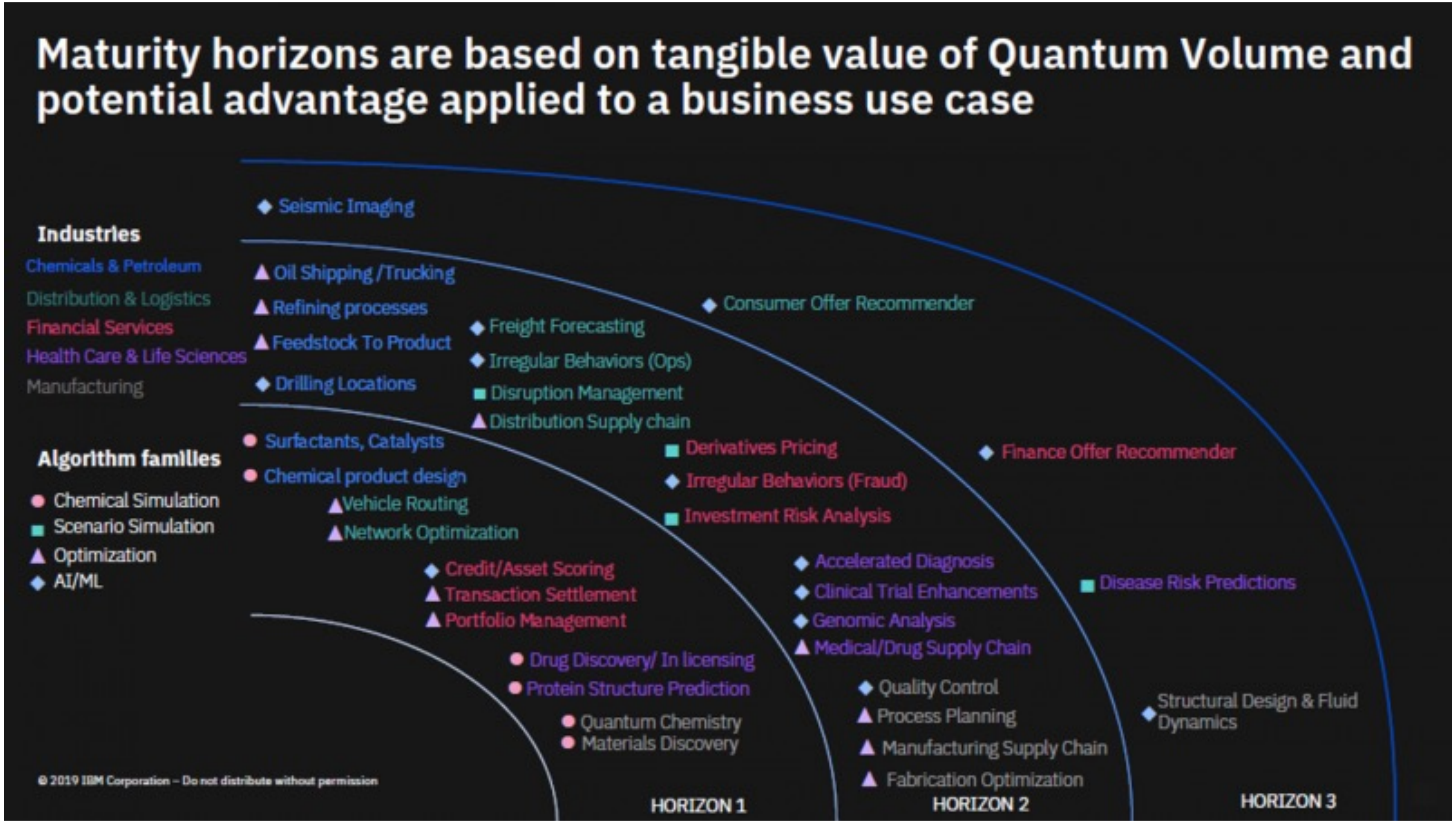
What can quantum computers do better ?

Quantum computing could solve a range of complex aerospace problems

- RESOLVING COMPLEX COMPUTATIONAL CHALLENGES
- IMPROVING CRYPTOGRAPHIC ALGORITHMS
- DEBUGGING MILLIONS OF LINES OF SOFTWARE CODE
- ADVANCING MACHINE LEARNING
- SPEEDING UP AIRCRAFT DESIGN

MMS 20192351. August 2019.

AIRBUS


Maturity horizons are based on tangible value of Quantum Volume and potential advantage applied to a business use case
Industries
Chemicals & Petroleum
Distribution & Logistics
Financial Services
Health Care & Life Sciences
Manufacturing
Algorithm families
Chemical Simulation
Scenario Simulation
Optimization
AI/ML
Seismic Imaging
Oil Shipping /Trucking
Refining processes
Feedstock To Product
Drilling Locations
Surfactants, Catalysts
Chemical product design
Vehicle Routing
Network Optimization
Credit/Asset Scoring
Transaction Settlement
Portfolio Management
Drug Discovery/ In licensing
Protein Structure Prediction
Quantum Chemistry
Materials Discovery
Freight Forecasting
Irregular Behaviors (Ops)
Disruption Management
Distribution Supply chain
Derivatives Pricing
Irregular Behaviors (Fraud)
Investment Risk Analysis
Accelerated Diagnosis
Clinical Trial Enhancements
Genomic Analysis
Medical/Drug Supply Chain
Quality Control
Process Planning
Manufacturing Supply Chain
Fabrication Optimization
Consumer Offer Recommender
Finance Offer Recommender
Disease Risk Predictions
Structural Design & Fluid Dynamics
HORIZON 1
HORIZON 2
HORIZON 3
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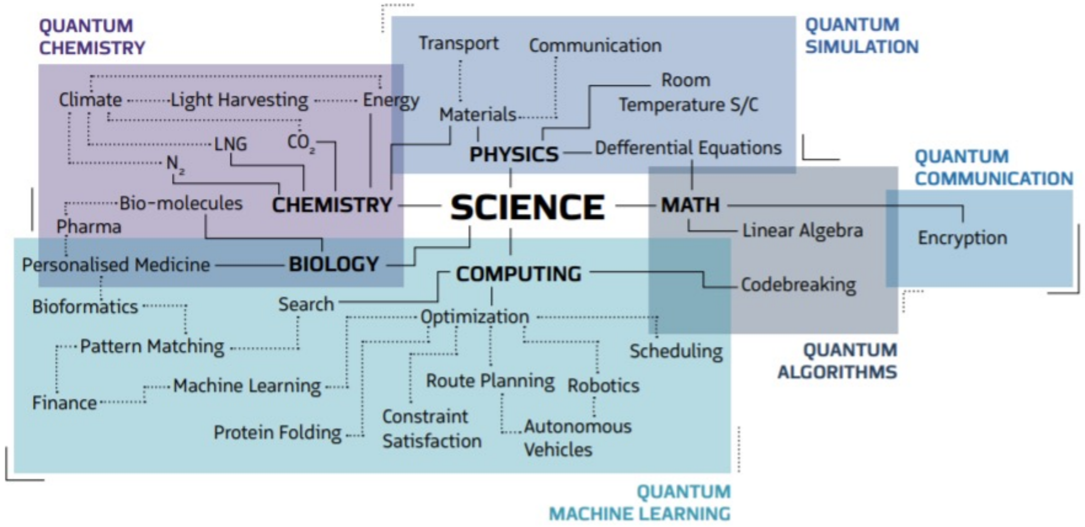
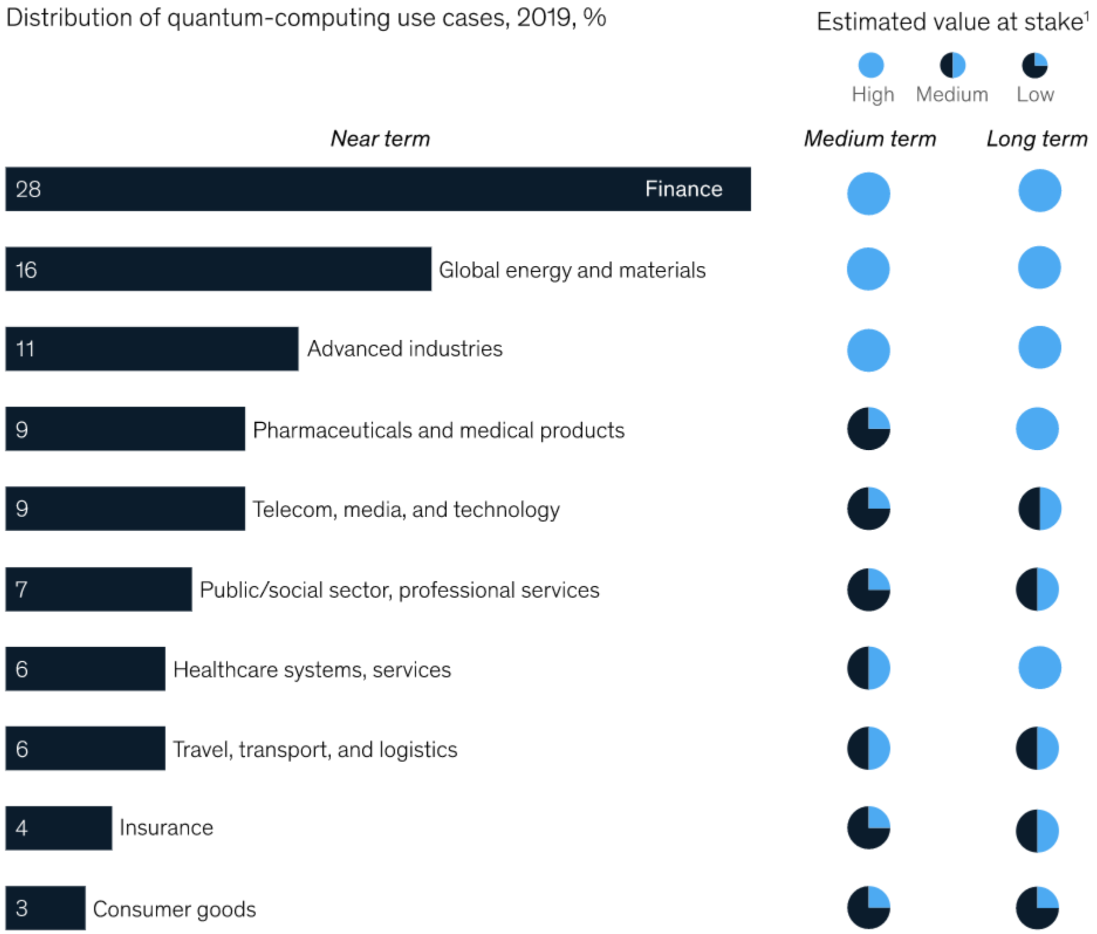


Figure 2

Potential applications for quantum computing (Source: Quantum Computing Market & Technologies – 2018-2024, Industry 4.0 Market Research,a division of HSRC, February 2018)

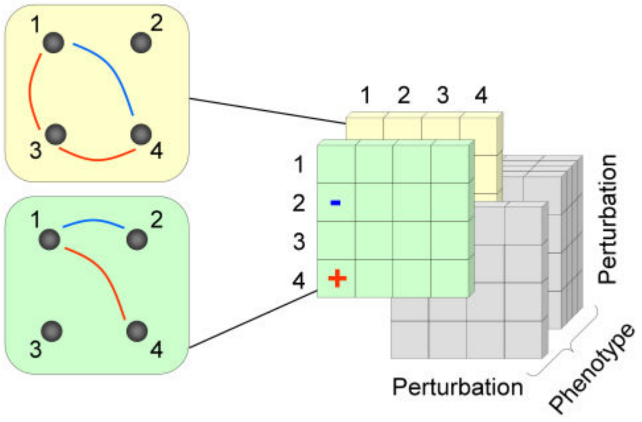
Who could create value with quantum computing?



[1]Approximate timing for medium term is by the year 2025; for long term, by the year 2035. Experts consider these values at stake to be a snapshot in time. Fully developed quantum computing will lead to additional value within and shifts between industry verticals.
Source: Expert interviews; McKinsey analysis

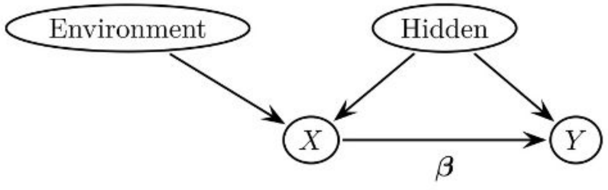
5. Quantum Computing para Biomedicina Avanzada

NCSA Healthcare Innovation + Mayo Clinic



Algoritmos cuánticos para genome-wide association studies (GWAS) con interacciones epistáticas desconocidas

Quantum signal processing de señales 1D, 2D y 3D

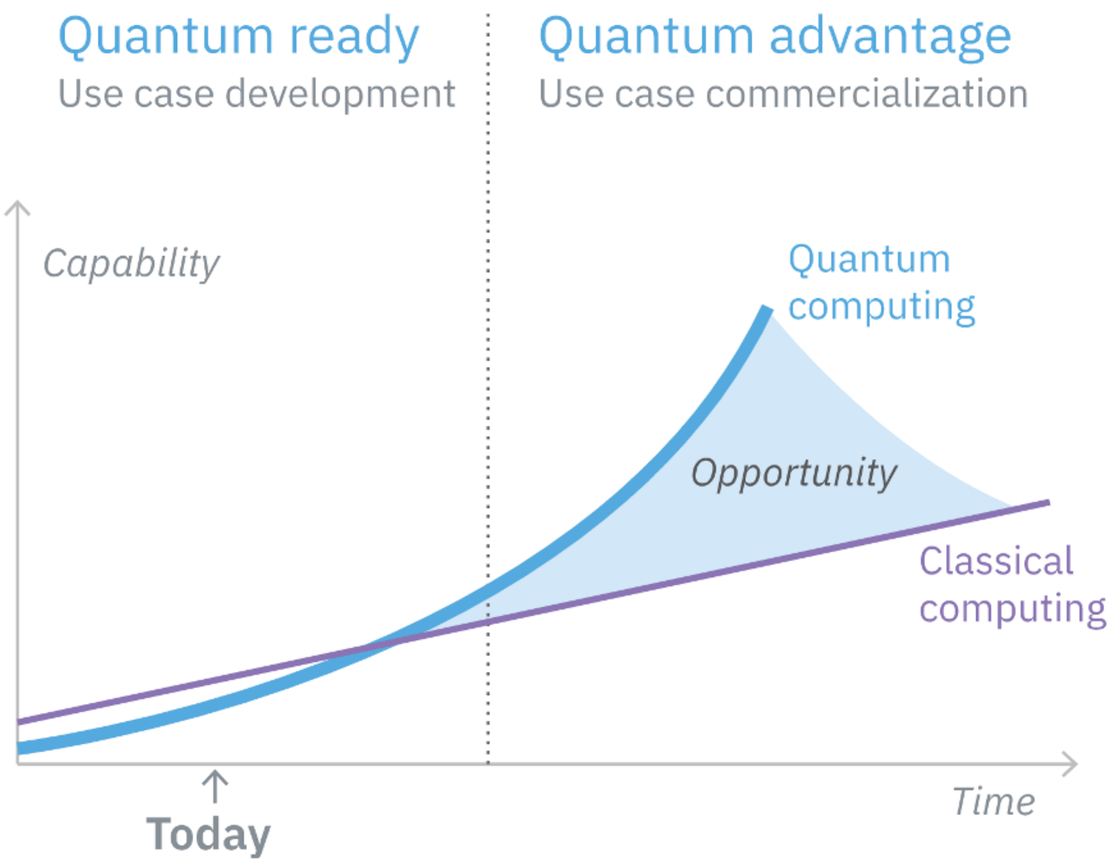


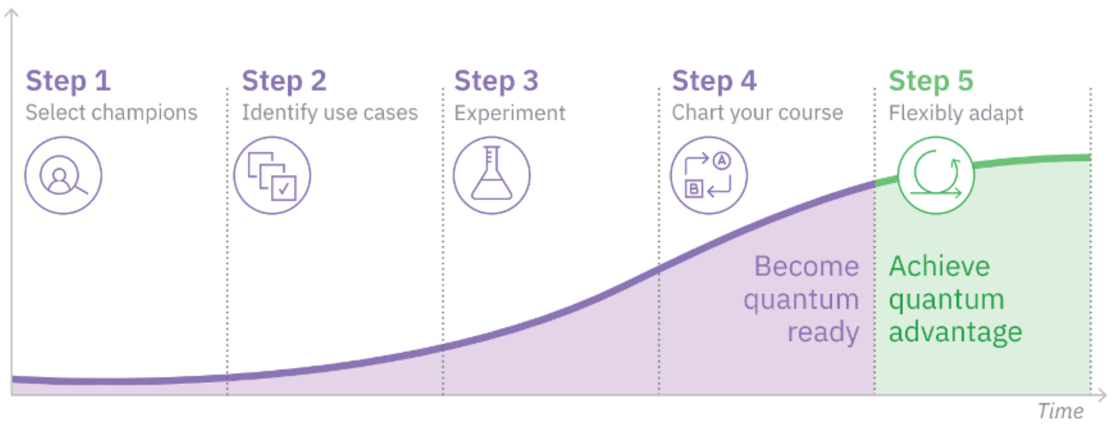
Inferencia causal cuántica para problemas clínicos y biomédicos

Otrps casos de uso

- Diseño de fármacos y modelado de química cuántica
- Quantum machine learning
- Optimización de modelos de riesgo
- Administración de portfolios dinámicos
- Logística
- Colocación de redes 5G

Tareas





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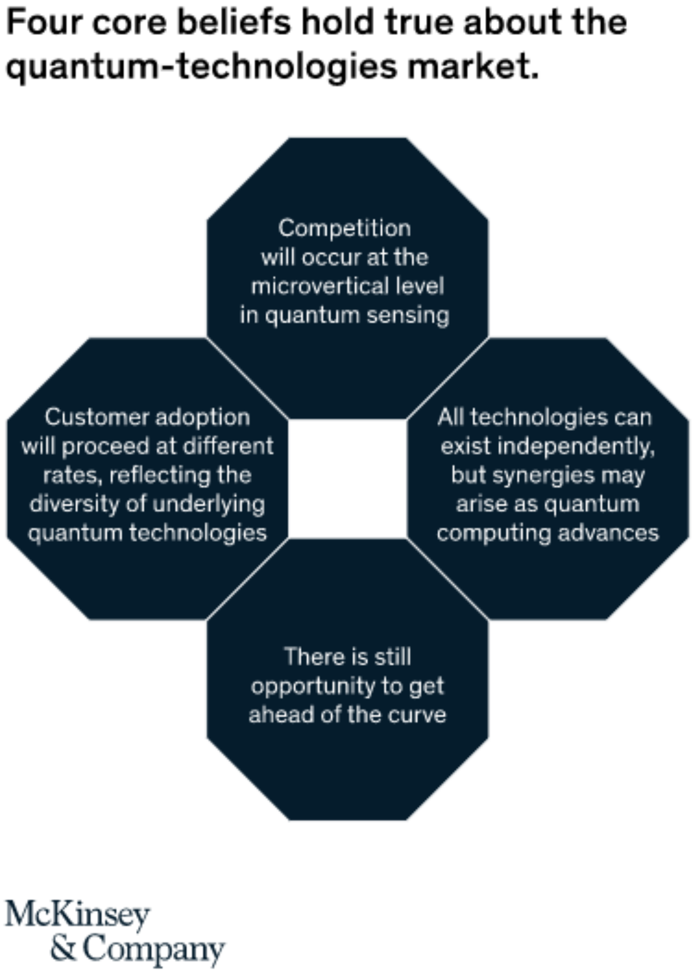
Invertir temprano, estratégicamente

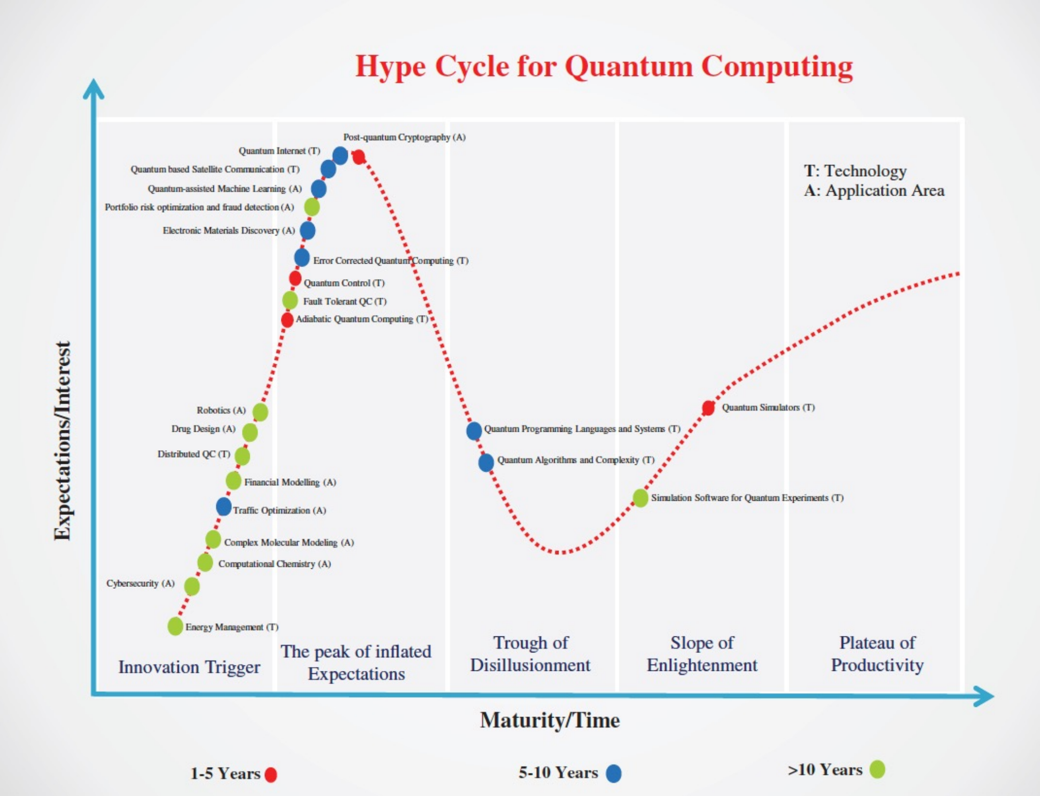


Las industrias y sectores que innoven de desarollo y adquisición de talento desde ya dominarán el acceso y uso de computación cuántica cuando los dispositivos alcancen tolerancia a fallos, y obtendrán los beneficios financieros respectivos

C-Suite: Desarrollo de un plan en fases de 10 años

- Exploración con socios expertos
- Invertir en investigación y desarrollo
- Madurar y escalar productos junto al hardware
- Colocar en operaciones

Sobrevivir el hype cycle en quantum requiere realismo y persistencia



Gill, S.S., Kumar, A., Singh, H., Singh, M., Kaur, K., Usman, M. and Buyya, R., 2022. Quantum computing: A taxonomy, systematic review and future directions. *Software: Practice and Experience*, *52*(1), pp.66-114

El papel principal de líderes en TI es administrar las expectativas de quienes invierten en quantum, mantenerse al tanto del estado del arte, y avanzar de forma persistente.

- Mantener el pulso del gap entre necesidades de negocio y posibilidades del hardware
- Identificar hitos y plataformas: retos, prototipos y proveedores en la nube
- Quantitative impact assessments of costs, risk and benefits
- Adopt Mayo Clinic’s motto: think big, start small, move fast

C-Suite: puntos clave para recordar

Market – $35B de inversión, $250M mercado con CAGR ~ 30% hacia $2B en esta década

Principles – fundamentalmente distinta a computación clásica, transformacional

Systems – moviéndose de infancia a adolescencia (NISQ), 10+ años antes de uso mainstream

Applications – necesidad de descubrir nuevos algoritmos, algoritmos existentes aplicables a una amplia gama de problemas difícules

Tasks – invest in workforce development and applications research, compact to scalable

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