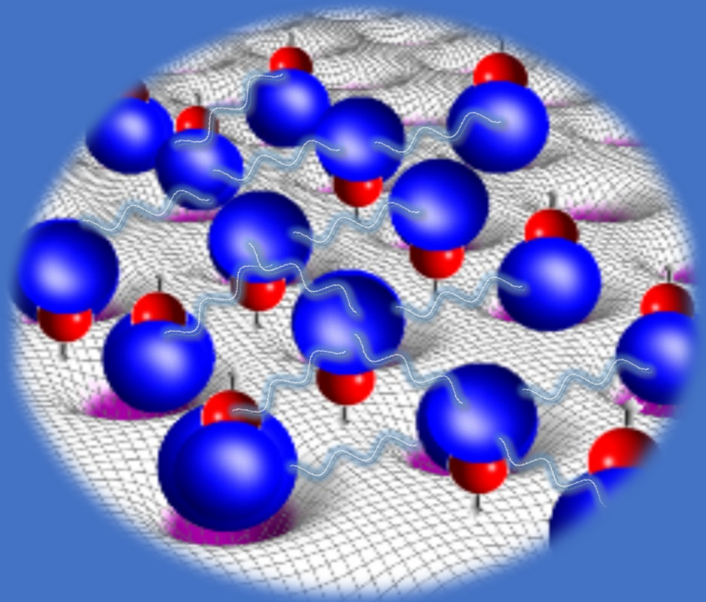
The Dream of a Common Language

international standards for the quantum economy



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U.S. Department of Commerce

Harmonization of Terminology in Standards for Quantum Technology

June 23, 2021

This talk

Standards – what are they & why do they matter

How standards fuel the technology lifecycle

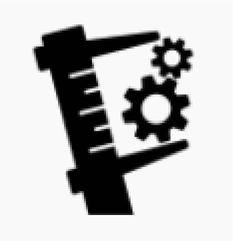
Quantum technology
- A lay of the land
- Quantum standards

Terminology standards: the dream of a common language

Yes, standards do matter

Courtesy: www.treehugger.com

Standards come in lots of flavors



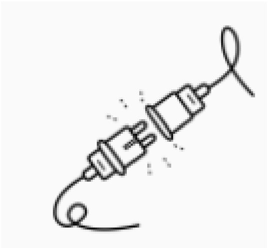
Physical standards & measurement protocols

Architectures

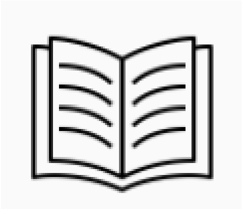
Procurement

Use Cases

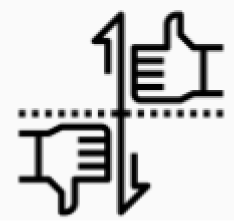
Guidelines,
Best practices



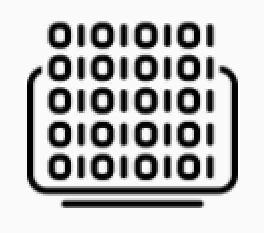
Interoperability



Terminology



Benchmarks & metrics



Software algorithms & languages

Certification & test protocols

Regulatory standards

And they're developed in lots of ways

- By:
  - Standards Development Organizations
  - Metrology Institutes
  - Consortium
  - Brute force

- With different ease of access
- With different voting privileges

- Different levels of ongoing support
- In different timeframes

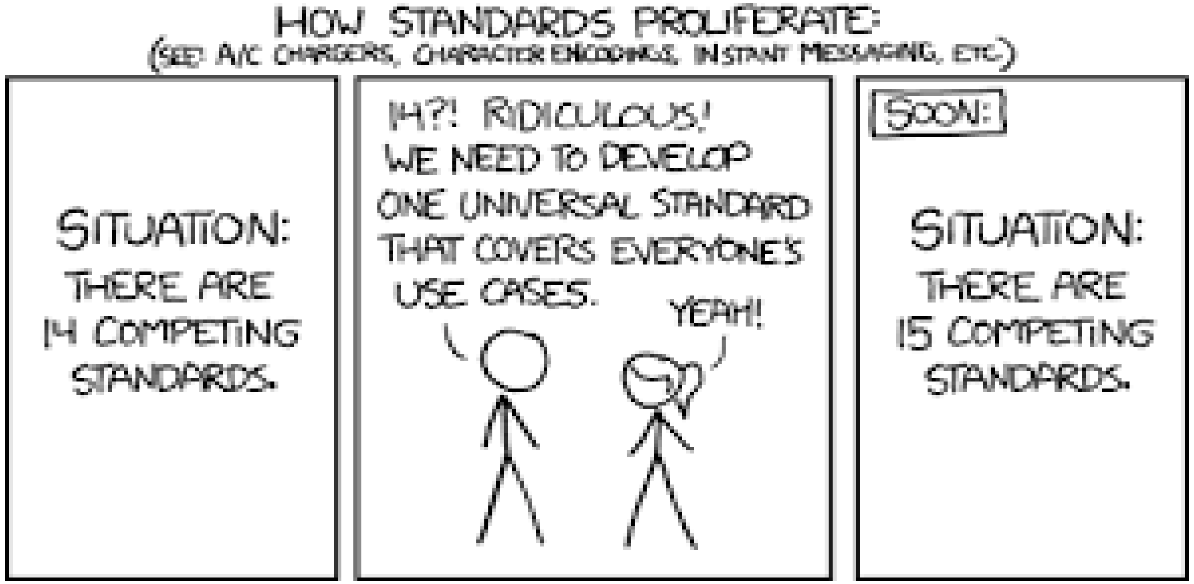
When standards work, they…

- Create a common language
- Create fair & open, plug & play markets
- Enable protection of health, safety and environment
- Spur innovation

$ Create business opportunities

When standards don't work, they…

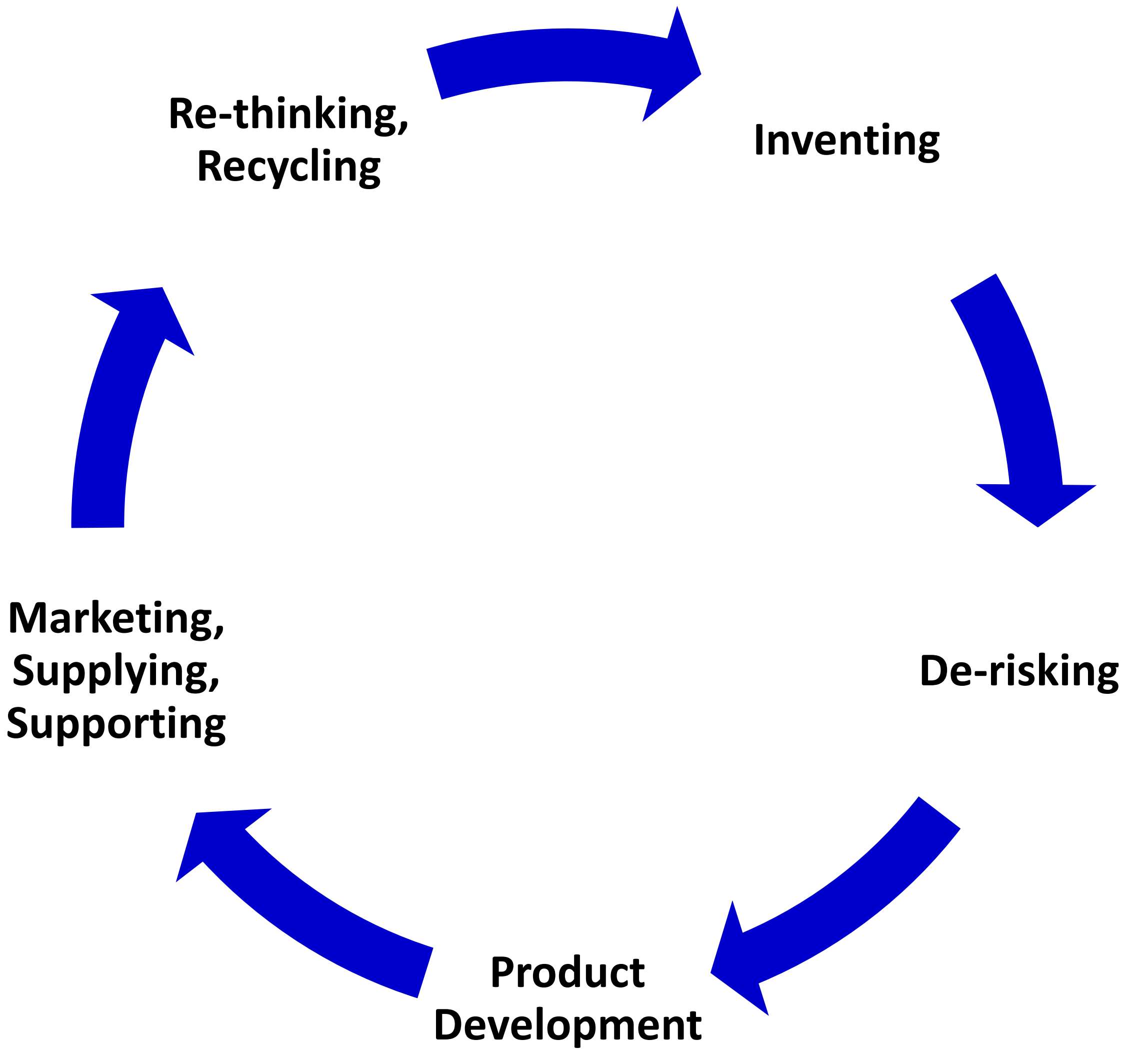
- Multiply!
- Give unfair political or market advantage
- Create barriers to trade and close markets
- Pick winners & losers / stifle innovation
- Entrench inferior technologies
- Impede the interoperability of products and systems



https://xkcd.com/927/

Reference: The ABCs of Standards Activities, NISTIR 7614, https://www.nist.gov/sites/default/files/nistir_7614.pdf

The circle of technology



The circle of technology

	What it is
Inventing	R&D
De-risking	Prototyping Validating Securing
Product Development	Engineering Scaling
Marketing, supplying, supporting	Engaging customers Logistics
Re-thinking / recycling	Learning from the field

The circle of technology

	What it is	What it takes
Inventing	R&D	Stable funding
De-risking	Prototyping Validating Securing	Understanding market, customer needs
Product Development	Engineering Scaling	Commercial investment Robust supply chain
Marketing, supplying, supporting	Engaging customers Logistics	Meeting a real commercial need Consumer trust Plug & play marketplace
Re-thinking / recycling	Learning from the field	Information from the field

The circle of technology

NIST

	What it is	What it takes	Standards
Inventing	R&D	Stable funding	**Terminology** **Test & measurement**
De-risking	Prototyping Validating Securing	Understanding market, customer needs	**Characterization & performance** **Metrics & benchmarks** **IT Security**
Product Dev.	Engineering Scaling	Commercial partner Robust supply chain	**Interface**
Marketing, supplying, supporting	Engaging customers Logistics	Consumer trust Plug & play marketplace Certification / validation	**Interoperability** **Testbeds** **Certification** **Procurement** **Supply chain communication**
Re-thinking / recycling	Learning from the field	Information from the field	**Industry 4.0**

Role of standards in technology evolution

Scientific revolutions don’t require standards; industrial revolutions do

	Standards
Inventing	Terminology Test & measurement
De-risking	Characterization & performance Metrics & benchmarks IT Security
Product Dev.	Interface
Marketing, selling, supporting	Interoperability Testbeds Certification Procurement Supply chain comm
Re-thinking / recycling	Industry 4.0

Map research results to product characteristics

Provide performance ground truth

Manage the hype
Compare competing technical approaches

Create market opportunities
through a plug & play framework

Establish consumer confidence

M2M logistics support,
Performance-to-design loopback

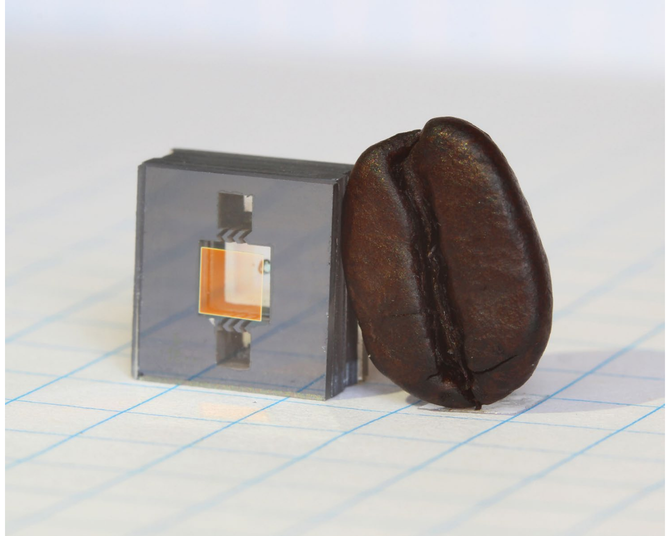
Quantum Sensing

NIST

Advantage: Exploit the quantum properties of nature to create intrinsically accurate sensors that beat conventional noise limits

Applications: biosensors for MRI and quantum-enhanced microscopy; gravimeters and accelerometers for navigation in GPS-denied environments

What's needed:
- Scaling of critical components, like lasers
- Integrated photonics
- Proving out new physics
- New metrology culture



Vapor cell used in next-generation chip-scale optical clock (NIST)

Where are we now?
- Commercially available chip-scale atomic clocks (TRL-9)
- Fledgling companies, sensor technologies, NIST on a Chip program (TRL 3-5)

Quantum Computing

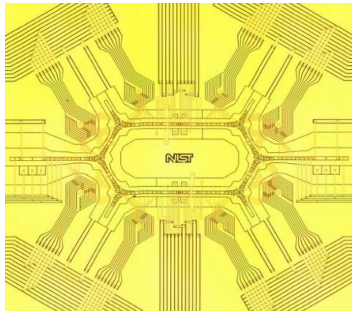
Advantage: New computing paradigm for optimization, cryptography and rapid solutions to intractable problems

Applications: breaking cryptography; simulating complex systems; solving the problems of quantum mechanics

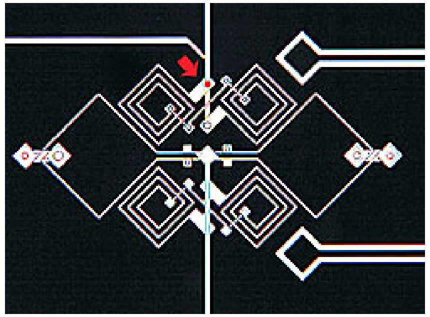
What's needed:

- Scalable cryogenics and environmental controls
- Transduction (RF, microwave, vibrating membranes…)
- Readout at room temperature
- Single photonics
- Error correction

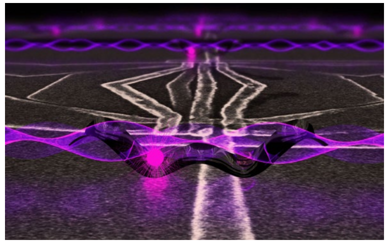
Atomic qubits



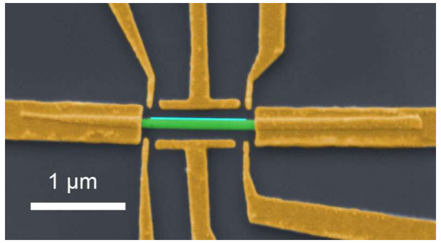
Superconducting qubits



Semiconductor spins



Topological qubits



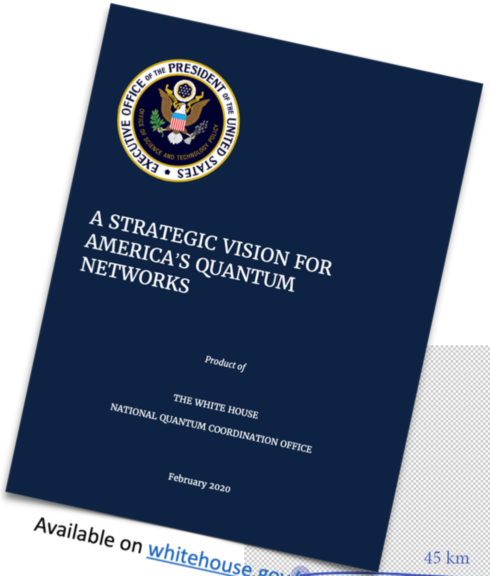
Where are we now?

- Commercially available quantum annealers (TRL-8)
- Noisy Intermediate-Scale Quantum (NISQ) research systems available via cloud (TRL-5)
- Full-scale, error corrected, gate-based computer decades offs (TRL-1)

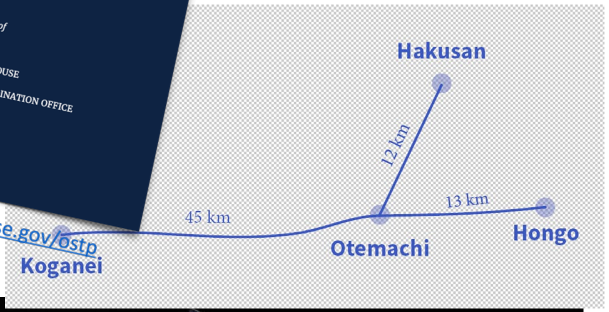
Quantum Communication & Networking

Advantage: Provide eavesdrop-proof communications and a new generation of network-accessible technologies through distributed entanglement

Applications: "blind" quantum computing allowing completely private cloud-based quantum computing; enhanced distributed sensing (a "sensor network" rather than a network of sensors)



Available on whitehouse.gov/ostp



What's needed:
- Components: quantum repeaters, memory, interconnects
- Sources and detectors
- Robust, affordable, compact cryogenics
- Terrestrial & space-based platforms

Where are we now?
- Simple QKD networks (TRL-7)
- Component technologies (TRL-2)
- Functional entanglement-based network is decades off

Standardization readiness & activity

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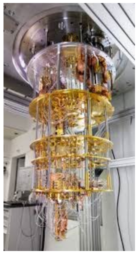
TRL 1	TRL 2, 3	TRL 4, 5	TRL 6, 7, 8, 9	Beyond TRLs
Basic Research	Feasibility Research	Prototype Development	Mature Technology	Market Established



Quantum memory

Quantum repeaters

Quantum computers

Quantum networks

Randomness generation

Single Photon Sources & Detectors

Quantum sensors

Post quantum encryption algorithms

Quantum Key Distribution

Quantum annealers

Technologies ⟵ ⟶ Standards

Terminology
IEEE P7130
ISO/IEC JTC1 WG14

Architectures
IETF/IRTF QIRG
ITU-T

Software languages

Benchmarks
QED-C prototypes

Measurement protocols

Use Cases
IETF/IRTF QIRG

Guidelines, Best practices

Software algorithms
NIST post-quantum crypto

Physical Standards
NIST, NRC, NPL, etc.

Interoperability
IEEE 1913 NETCONF/YANG
IEC TC86 – cables, fibres
ITU-T

Procurement

Regulatory standards

Certification/test protocols
ETSI QKD
ISO/IEC JTC1 SC27 QKD

Barbara Goldstein, NIST

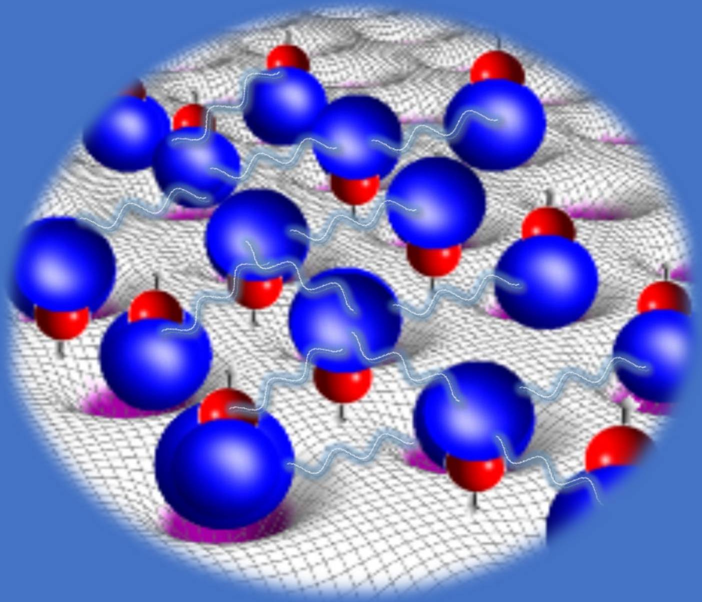
Standardization Readiness Levels – a first pass

NIST

SRL	Stage of Technology Development	TRL	Standardization activities to consider beginning
1	Basic research	1: Basic principles observed 2: Concept / application formulated	Identify critical measurements needed
2	Feasibility research • Multiple independent research groups	3: Proof of concept	• Terminology standards • Test & measurement standards
3	Prototype development • Commercial R&D	4: Component / subsystem validation in lab 5: Component / subsystem validation in relevant environment	• Characterization and performance standards • Metrics & benchmarks
4	Product development • Multiple companies	6: System / subsystem prototype demo – relevant environment 7: System demo in relevant environment	Interface standards
5	Commercial products offered by multiple companies	8: System completed & qualified 9: System proven under expected operating conditions	• Testbeds • Certification standards • Procurement standards

Terminology standards

the dream of a common language



Terminology standards – why?

Bridges communities

- Academic – Industrial Research – Suppliers – Users
- Creates a common perspective, feedback loop

Builds communities

- An "easy" place to start… and to start getting to know each other

Barbara’s wish list

Patience

- Be **science-based**: Don’t start standards before the science has matured
- Be **market-driven**: Don’t push standards before the market is ready

Coordination

- Just because there’s no Queen of Quantum Standards shouldn’t make it a free-for-all

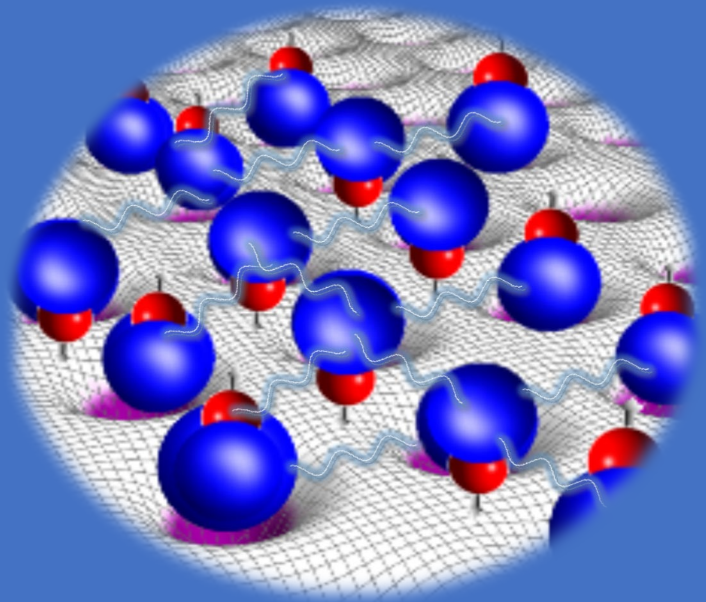
Collaboration

- Multi-SDOs -> common standards

Quality, not quantity

- No more YAQWPs (yet another quantum white paper)
- More is definitely not better!

Looking forward to our discussion!



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