The Dream of a Common Language

international standards for the quantum economy

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Harmonization of Terminology in Standards for Quantum Technology
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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 – what are they & why do they matter?

Standards come in lots of flavors

- Physical standards & measurement protocols
- Guidelines, Best practices
- Use Cases
- Architectures
- Interoperability
- Certification & test protocols
- Regulatory standards
- Procurement
- Terminology
- Benchmarks & metrics
- Software algorithms & languages
Standards – what are they & why do they matter?

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

How standards fuel the technology lifecycle

The circle of technology

- Inventing
- De-risking
- Marketing, Supplying, Supporting
- Product Development
- Re-thinking, Recycling
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<td><strong>De-risking</strong></td>
<td>Prototyping, Validating, Securing</td>
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<tr>
<td><strong>Product Development</strong></td>
<td>Engineering, Scaling</td>
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<tr>
<td><strong>Marketing, supplying, supporting</strong></td>
<td>Engaging customers, Logistics</td>
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## The circle of technology

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<th>Stage</th>
<th>What it is</th>
<th>What it takes</th>
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<td>Inventing</td>
<td>R&amp;D</td>
<td>Stable funding</td>
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<tr>
<td>De-risking</td>
<td>Prototyping</td>
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<td>Product Development</td>
<td>Engineering</td>
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<td>Scaling</td>
<td>Robust supply chain</td>
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<tr>
<td>Marketing, supplying, supporting</td>
<td>Engaging customers</td>
<td>Meeting a real commercial need</td>
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<td>Logistics</td>
<td>Consumer trust</td>
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<td>Plug &amp; play marketplace</td>
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<td>Information from the field</td>
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# The circle of technology

## What it is

<table>
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<th>Terminology Test &amp; measurement</th>
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<tbody>
<tr>
<td>De-risking</td>
<td>Prototyping</td>
<td>Understanding market, customer needs</td>
<td>Characterization &amp; performance Metrics &amp; benchmarks IT Security</td>
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<tr>
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<td>Validating,</td>
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<td>Securing</td>
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<tr>
<td>Product Dev.</td>
<td>Engineering</td>
<td>Commercial partner Robust supply chain</td>
<td>Interface</td>
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<td>Scaling</td>
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<tr>
<td>Marketing,</td>
<td>Engaging customers</td>
<td>Consumer trust Plug &amp; play marketplace Certification / validation</td>
<td>Interoperability Testbeds Certification Procurement Supply chain communication</td>
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<tr>
<td>supplying,</td>
<td>Logistics</td>
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<td>supporting</td>
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<tr>
<td>Re-thinking /</td>
<td>Learning from the field</td>
<td>Information from the field</td>
<td>Industry 4.0</td>
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<td>recycling</td>
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</table>
**Role of standards in technology evolution**

**Scientific revolutions don’t require standards; industrial revolutions do**

<table>
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<tr>
<th>Standards</th>
<th>Map research results to product characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventing</td>
<td>Provide performance ground truth</td>
</tr>
<tr>
<td>De-risking</td>
<td>Manage the hype</td>
</tr>
<tr>
<td></td>
<td>Compare competing technical approaches</td>
</tr>
<tr>
<td>Product Dev.</td>
<td>Create market opportunities through a plug &amp; play framework</td>
</tr>
<tr>
<td>Marketing, selling, supporting</td>
<td>Establish consumer confidence</td>
</tr>
<tr>
<td>Re-thinking / recycling</td>
<td>M2M logistics support, Performance-to-design loopback</td>
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</tbody>
</table>

- **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, Industry 4.0
- **Re-thinking / recycling**:
**Quantum Sensing**

**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

**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

**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 off (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)

**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
Quantum standards – when is it time?

Standardization readiness & activity

<table>
<thead>
<tr>
<th>TRL 1</th>
<th>TRL 2, 3</th>
<th>TRL 4, 5</th>
<th>TRL 6, 7, 8, 9</th>
<th>Beyond TRLs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Research</td>
<td>Feasibility Research</td>
<td>Prototype Development</td>
<td>Mature Technology</td>
<td>Market Established</td>
</tr>
</tbody>
</table>

Quantum memory
Quantum repeaters
Quantum computers
Quantum networks

Randomness generation
Single Photon Sources & Detectors
Quantum sensors
Post quantum encryption algorithms
Quantum annealers

Terminology
IEEE P7130
ISO/IEC JTC1 WG14

Architectures
IETF/IRTF QIRG
ITU-T

Software languages

Use Cases
IETF/IRTF QIRG

Guidelines, Best practices

Physical Standards
NIST, NRC, NPL, etc.

Measurement protocols

Benchmarks
QED-C prototypes

Software algorithms
NIST post-quantum crypto

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

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

Barbara Goldstein, NIST
### Standardization Readiness Levels – a first pass

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