The Birth and Development of an Industry

First Transistor, 1947
William Shockley, John Bardeen, and Walter Brattain

INDUSTRY & INFRASTRUCTURE

Supply Chain of Enabling Technologies

- Wafer processing
- Wet cleans
- Cleaning by solvents
- Piranha solution
- RCA clean
- Photolithography
- Ion implantation
- Dry etching
- Wet etching
- Plasma ashing
- Thermal treatments
- Rapid thermal anneal
- Furnace anneals
- Thermal oxidation
- Chemical vapor deposition (CVD)
- Physical vapor deposition (PVD)
- Molecular beam epitaxy (MBE)
- Electrochemical deposition (ECD)
- Chemical-mechanical planarization (CMP)
- Wafer testing
- Wafer backgrind
- Die preparation
- Wafer mount
- Die cutting
- IC packaging
- Die attachment
- IC bonding
- Wire bonding
- Thermosonic
- Flip chip
- Wafer bond
- Tape automation
- IC encapsulation
- Baking
- Plating
- Lasermarking
- Trim and form
- IC testing

2018, IC (12”, < 10 nm)
Quantum Economic Development Consortium (QED-C)

.... Will help accelerate the Quantum Industry by fostering a robust Supply Chain.

- **Definition of a Consortium**: an agreement, combination, or group of companies formed to undertake an enterprise beyond the resources of any one member

- **SRI has been contracted** to establish a Quantum Economic Development Consortium for the emerging Quantum Industry

The “QED-C”
Quantum Enabling Device Development Continuum

<table>
<thead>
<tr>
<th>STAGE &amp; TRL:</th>
<th>Basic R&amp;D</th>
<th>Application R&amp;D</th>
<th>Device Prototypes</th>
<th>Enabling Component Development</th>
<th>Prototype Components and Subsystems</th>
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</thead>
<tbody>
<tr>
<td>EFFICIENCIES:</td>
<td>Public/Private Support: Funding &amp; Collaboration</td>
<td>Introduce New Common Enabling Devices Performance Standards</td>
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<td>ENGAGED DISCIPLINES:</td>
<td>AMO Physics / Scientific Theory / R&amp;D / Materials</td>
<td>T&amp;E / Engineering Design &amp; Development</td>
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QED-C Quantum Consortium Activities:
- De-risked components
- Robust infrastructure
- Common standards
- Testbeds

Competitive R&D And Industry Activities:
- Production Equipment Fabrication & Sales
- COTS Device Manufacturing & Sales
- Full Quantum Systems
- Deploy Quantum Systems at Utility Scale

Create Device Production Equipment Standards
COTS Device & Systems Performance Standards
The Purpose of the QED-C is:

1. To support enabling technology R&D: e.g. quantum device components, instrumentation, and performance standards

2. To facilitate industry coordination and interaction with government agencies

3. To provide the government with a collective industry voice in guiding R&D investment priorities and quantum workforce issues
The Objectives of the QED-C

- Determine workforce needs essential to the development of quantum technologies;
- Provide efficient public-private sector coordination;
- Identify technology solutions for filling gaps in research or infrastructure;
- Highlight use cases and grand challenges to accelerate development efforts; and
- Foster sharing of intellectual property, efficient supply chains, technology forecasting and quantum literacy.
The Value Proposition of the QED-C:  \[ \frac{Output}{Input} \gg 1 \]

- Competitive Benefits: The US Quantum Industry is nascent and fragmented (along transition, technical, organizational, sector and funding dimensions), and is \( \leq \), or \( \ll \), Near-Peer: EU, UK, China... \textit{The QED-C will help foster industry collaboration and coordination.}

- Close Enabling Technology Gaps: \textit{The QED-C will help build a stronger supply chain for research and industrial productivity.}

- \textbf{The QED-C offers efficiency over “standard” RFP processes:}
  - Coordinated public/private funding, and coordinated funding among multiple Federal agencies
  - Encourages non-traditional industry partners

- It’s not about spending more... \textit{The QED-C will spend smarter!}

- The US Quantum Industry will benefit from performance and evaluation standards... \textit{The QED-C will facilitate SDO participation.}
Proposed Membership

The QED-C is primarily “by and for US Industry” (at all sizes and stages) to support US Economic Growth.

- Includes Members that would self-identify as “members of the quantum industry community”, or “participating in the emerging quantum industry”.
- Also includes equipment suppliers, instrumentation OEM’s, materials companies, service providers, End-Users, etc.

QED-C will also engage:

- Academic Community
- Standards Development Organizations
- Professional Societies
- Investment Community
- International Partnerships
Proposed QED-C Deliverables

Years 1 & 2:
- Workforce Requirements Analysis and Actions
- Gap Identification and Needed Enabling Technology and Infrastructure
- Needs Assessments for Instruments and Tools
- Input to USG for R&D Programs

Year 2+
- Cost-Shared Funding of Enabling Technology R&D Programs in the Consortium

Potential Out-Year Activities:
- Facilitate Quantum Standards and Metrics
- Use Cases and Studies of Q-Advantage
- Q-Community Representation
- Scientific and Market Forecasts
DRAFT Proposed Phased QED-C Organizational Structure

- **Technical Advisory Council**
  - All CNS Domains
  - Identifies Technical Gaps
  - Defines Enabling Technologies
  - Establishes R&D Themes
  - Issues and Evaluates RFP’s and Proposals (Rules/OCI)
  - Monitors R&D Progress

- **Executive Director**
  - Responsible for Technical Direction
    - Chairs Technical Council
    - Supervises R&D Programs
    - Drives Technology Advancement & Success

- **Deputy Director of Operations**
  - Responsible for Operations, Federal Relationships and Cost Share
    - Manages Cooperative Agreement
    - Manages R&D Funding and Cost Share
    - Financial Planning

- **Director of Science & Technology**
  - Responsible for Tech Transition and Licensing
    - Responsible for all IP & Manages Licensing
    - New Partnerships
    - Links to VC Community

- **Director of Commercialization**
  - Responsible for all External and Internal Communications
    - Leads Studies and Outreach Programs
    - External Comms and Press
    - Consortium Events and Briefings

- **Governing Board**
  - Governs QED-C and Develops Operating Principles
    - Composition: 3 Large Industry/2 Small Industry/2 Federal
    - Includes Non-Voting Advisory Board Members
    - Governs R&D Allocations and Ratifies RFP’s

  - Executive Management of QED-C
    - Vision and Strategy
    - Membership Recruitment
    - Liaison and Advocacy

  - Responsible for External and Internal Communications
    - Leads Studies and Outreach Programs
    - External Comms and Press
    - Consortium Events and Briefings

2018 - 2020 Timeframe
Governing Board

- Board Composition (3-2-2)
  - Large Industrial members at highest dues levels (3)
  - Representatives of medium and small-size companies (2)
  - Federal Partners (2)
  - (Possibly) non-voting state or regional economic development representatives
  - Others as approved by GB
Simple IP Policy:

IP Ownership

“Ownership follows Invention” rule so that Development Partners:

- Retain full ownership rights to the IP that the Development Partner conceives pursuant to a QED-C Development Agreement using QED-C Funding
- Retain full ownership rights to its own background IP, if any
Consortium and IP Owner Rights:

- **USG License**: Grant to the USG a non-exclusive, nontransferable, paid-up, worldwide perpetual license to use the Consortium IP for any Government purpose.

- **Evaluation License**: Grant to each QED-C Member a non-exclusive, royalty-free, non-transferable license for the duration of Member’s membership to use the Consortium IP (without the right to sublicense) for the limited purposes of further evaluation and R&D.

- **Commercial License**: On request, grant to any QED-C Member a non-exclusive, transferable worldwide license (with the right to sublicense) on commercially reasonable, nondiscriminatory (“RAND”) terms.

- **Third-Party Licenses**: On terms negotiated by the Development Partner.
Proposed Phased-Dues Structure

- Phased-in dues structure
- In-kind commitments possible for governance and technical programs
- Cost-share anticipated for leveraged USG R&D

**Year 1 & 2 Deliverables:**
- Workforce requirements analysis and actions
- Gap identification and needed enabling technology and infrastructure
- Input to USG for R&D programs

**Year 2+ Deliverables:**
- Cost-shared funding of enabling technology R&D programs in the Consortium + year 1 and 2 + out-year deliverables
- Use cases and studies of Q-Advantage
- Quantum standards and metrics
- Q-Community representation/unified voice
- Scientific and market forecasts

*Companies joining early (years 1 and 2) could receive credit in year 3.*
Companies with signed LOI’s (as of 10/10/18)

- AO Sense
- AT&T
- Boeing
- BraKet
- Cold Quanta
- Corning
- Entanglement Institute
- GE Global Research
- Google
- Harris
- IBM
- Intel
- IonQ
- Janis Research
- Keysight
- KLA-Tencor
- Montana Instruments
- Psi Quantum
- QC Ware
- Quantum Circuits, Inc.
- Raytheon/ Raytheon-BBN
- Rigetti
- SRI
- Toptica
- Zyvex
Next Steps

- 25 Signed Letters of Intent (LOI), plus waiting on several additional
- Initiating Year 1 Tasks (@NIST Boulder Meeting—October 29th & 30th, 2018):
  - Form Governing Board and Technical Advisory Council
  - Form TAC Sub-committees (e.g. Workforce, Enabling Technologies, End Use, R&D Thrusts, Standards, etc.)
  - Participation Agreements (PA)
  - Determine final Governance, IP Rules, Dues, Membership
  - Executive Search to Hire Director
  - Prepare for Funding (Vehicles, RFP’s, Proposal Selection, etc.)
  - Set Timetable for Initial Operating Years
  - Kick-Off Workforce Analysis and R&D Initiatives