IEEE SA STANDARDS ASSOCIATION

Standardization Roadmap on Quantum Applications

Industry Connections Activity Initiation Document (ICAID)

Version: 1.0, 16 November 2023

IC23-014-01 Approved by the CAG 22 December 2023

Instructions

- Instructions on how to fill out this form are shown in red. Please leave the instructions in the final document and simply add the requested information where indicated.
- Spell out each acronym the first time it is used. For example, "United Nations (UN)."
- Shaded Text indicates a placeholder that should be replaced with information specific to this ICAID, and the shading removed.
- Completed forms, in Word format, or any questions should be sent to the IEEE Standards Association (IEEE SA) Industry Connections Committee (ICCom) Administrator at the following address: industryconnections@ieee.org.
- The version number above, along with the date, may be used by the submitter to distinguish successive updates of this document. A separate, unique Industry Connections (IC) Activity Number will be assigned when the document is submitted to the ICCom Administrator.

1. Contact

Provide the name and contact information of the primary contact person for this IC activity. Affiliation is any entity that provides the person financial or other substantive support, for which the person may feel an obligation. If necessary, a second/alternate contact person's information may also be provided.

Name: Manjunath Ramachandra Iyer
Email Address: manjunath.iyer@wipro.com
Employer: Wipro
Affiliation: Wipro

IEEE collects personal data on this form, which is made publicly available, to allow communication by materially interested parties and with Activity Oversight Committee and Activity officers who are responsible for IEEE work items.

2. Participation and Voting Model

Specify whether this activity will be entity-based (participants are entities, which may have multiple representatives, one-entity-one-vote), or individual-based (participants represent themselves, one-person-one-vote).

Individual-Based

3. Purpose

3.1 Motivation and Goal

Briefly explain the context and motivation for starting this IC activity, and the overall purpose or goal to be accomplished.

The revolutions in quantum physics and engineering have led to new and (previously) unthinkable applications. New applications are emerging every day despite limitations for the large-scale deployment of quantum-based technologies.

The proposed roadmap plays a vital role in indicating application-readiness and providing guidance for the stakeholders including investors, researchers, start-up founders, existing industries, policymakers, regulators, and the like.

Although numerous roadmap documents exist today with different scopes, purposes, and target audiences, their content and flow share many commonalities. They are open-ended, and they may not be closely related to the business problems of the respective prevailing technologies. As such, investors are unable to determine return-on-investment (RoI) potential. Researchers, start-up founders, and other stakeholders work in silos to better preserve intellectual property and future earnings potential. Regulators and policymakers are often non-specialized in the nuances required to realize an industry from the ground on up and therefore are forced to remain retroactive and unable to establish anything beyond a patchwork of overlapping rules and legislation that take years to harmonize internationally. Hence, there is a need to identify business cases, associated issues, and the relevant quantum-based technologies to realize the same. The goal is to link these business problems to prevailing technology and standardization roadmaps so that stakeholders are aligned in their preparedness.

This Industry Connections Activity serves the purpose of

- Identifying use cases relevant to existing industries that are realizable with prevailing technologies at different points in time.
- Identifying limitations and shortcomings of existing technologies and their workarounds.
- Reformulating research problems with respect to anticipated technological and standardization adoption.
- Linking recommendations with existing technology roadmaps.
- Identifying standardization needs e.g., supply chain management, reliability of systems and system infrastructure, norms for international distribution of products).
- Linking standardization to business problems and the associated technologies along the timeline being presented.

Essentially the proposal is for the development of a Roadmap addressing business problems at various points on the time line.

3.2 Related Work

Provide a brief comparison of this activity to existing, related efforts or standards of which you are aware (industry associations, consortia, standardization activities, etc.).

Numerous roadmap documents exist today for quantum technologies. "The Quantum Technologies Roadmap: A European Community View"[1] provides a comprehensive technological roadmap encompassing quantum communication, quantum computation, quantum metrology, and quantum sensing. The "Standardization Roadmap on Quantum Technologies,"[2] which was the most recent roadmap published at the time this Initiation Document was drafted, provides a comprehensive view of quantum technologies more generally.

Several government agencies and organizations have their own quantum technologies roadmaps. In the roadmap of the Australian military[3], only three technological pillars (quantum sensors and imaging, quantum computing, and quantum communications) are considered. The US Department of Energy "Report of the DOE Quantum Internet Blueprint Workshop"[4] details projected milestones to establish a nationwide quantum-based Internet. The British government[5] has defined a national strategy to more generally address deficiencies that exist in quantum-related research and development, which is similar to the quantum technology research and development roadmap published by the Republic of the

[1] Acín, A., I. Bloch, H. Buhrman, T. Calarco, C. Eichler, J. Eisert, D. Esteve, et al., "The quantum technologies roadmap: A European community view," *New Journal of Physics*, vol. 20, no. 8 (August 15, 2018): 080201. https://doi.org/10.1088/1367-2630/aad1ea.

[2] CEN/CENELEC Standardization Roadmap on Quantum Technologies: 2023-03

[3] Robotic and Autonomous Systems Implementation Coordination Office (RICO), Future Land Warfare Branch, [Australian] Army Headquarters, "Army Quantum Technology Roadmap," (April 2021). https://researchcentre.army.gov.au/sites/default/files/RD5734_Quantum%20Roadmap%20WEB.pdf.

[4] Awschalom, D., M. Blodgett, G. Borsuk, G. Carini, T. Chapuran, J. Chow, P. Dabbar, et al., "Report of the DOE quantum internet blueprint workshop: From long-distance entanglement to building a nationwide quantum internet," *U.S. Department of Energy, Office of Science, Office of Advanced Scientific Computing Research* (July 30, 2020). https://www.energy.gov/sites/prod/files/2020/07/f76/QuantumWkshpRpt20FINAL_Nav_0.pdf.

[5] Department for Science, Innovation & Technology, "National Quantum Strategy," *U.K. Government* (March 2023). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1142942/national_quantum_strategy.pdf.

Philippines.[6] IBM[7] focuses on quantum materials and devices, while Russian Railways[8] emphasizes on government cooperation (including with former Soviet states) for quantum communications technologies and the quantum Internet of Things.

3.3 Previously Published Material

Provide a list of any known previously published material intended for inclusion in the proposed deliverables of this activity.

Not applicable.

3.4 Potential Markets Served

Indicate the main beneficiaries of this work, and what the potential impact might be.

Quantum technologies have potential to transform multiple markets, including banking and finance, healthcare, insurance, power distribution, traditional and sustainable energy, logistics, chemical and materials science, defense, aerospace, enterprise, and so forth. This work is expected to be useful for investors, policymakers, researchers, start-up founders, existing industries, and sustainable development organizations.

Firstly, it pulls together the different enabling technologies respective to their overlap and corresponding advances in artifact, protocol, and process development.

Secondly, it identifies problems in the implementation of different quantum technologies and provides a roadmap to realize them for general consumption. It helps business plan for the stage-wise implementation and realization of different technologies so that advances are accelerated. Researchers and policymakers can also plan their activities accordingly.

Lastly, it identifies opportunities to realize appropriate business solutions at various stages within the timeline so that technological evolution is smooth and continuous. This would be helpful for potential investors wishing to project their RoI, or existing industries and start-ups needing to arrange for infrastructure and supply chains in a phased manner.

3.5 How will the activity benefit the IEEE, society, or humanity?

[6] "Library: Roadmaps," *Department of Science and Technology, Philippine Council for Industry, Energy and Emerging Technology Research and Development, Republic of the Phillippines* (accessed September 5, 2023). https://pcieerd.dost.gov.ph/library/road-maps#emerging-technology-development-division-roadmap.

[7] "The IBM quantum development roadmap," *IBM* (November 8, 2022). https://www.ibm.com/quantum/roadmap.

[8] Kurasheva, A., and E. Kinyakina, "Russian Railways proposed to create standards for quantum technologies," *Vedomosti* (August 25, 2022). https://www.vedomosti.ru/technology/articles/2022/08/25/937508-rzhd-kvantovih-tehnologii [Russian].

Describe how this activity will benefit the IEEE, society, or humanity.

This Industry Connections Activity helps to define the directions for precise and pointed standardization activities. The standards so defined would directly benefit organizational investors, researchers, and the like. It furthermore helps outside investors place their monies towards stable, sustainable technological growth and evolution at the times best projected to maximize their RoI. Finally, it accelerates the deployment of quantum-based technologies and their communal adoption.

4. Estimated Timeframe

Indicate approximately how long you expect this activity to operate to achieve its proposed results (e.g., time to completion of all deliverables).

Expected Completion Date: 12/2025

IC activities are chartered for two years at a time. Activities are eligible for extension upon request and review by ICCom and the responsible committee of the IEEE SA Board of Governors. Should an extension be required, please notify the ICCom Administrator prior to the two-year mark.

5. Proposed Deliverables

Outline the anticipated deliverables and output from this IC activity, such as documents (e.g., white papers, reports), proposals for standards, conferences and workshops, databases, computer code, etc., and indicate the expected timeframe for each.

- **A roadmap document ready for use by all interested stakeholders**.

The document is expected to contain business problems at different points in time, solutions with prevailing technologies, availability of applicable standards, and evolution of supporting research activities. Unlike the other roadmaps, this document will be linked to business problems and indicates the readiness of different standards and technologies available at different times to provide solutions. It is expected to be available by December 2025. The initial task comprises setting up the group, study of existing roadmaps, Business problems and use cases at present and future, the Technologies, Market for Quantum technologies, Research directions, etc. The roadmap document is expected by the middle of 2025, providing ample time for reviews and revisions before submission.

5.1 Open Source Software Development

Indicate whether this IC Activity will develop or incorporate open source software in the deliverables. All contributions of open source software for use in Industry Connections activities shall be accompanied by an approved IEEE Contributor License Agreement (CLA) appropriate for the open source license under which the Work Product will be made available. CLAs, once accepted, are irrevocable. Industry Connections Activities shall comply with the IEEE SA open source policies and procedures and use the IEEE SA open source platform for development of open source software. Information on IEEE SA Open can be found at https://saopen.ieee.org/.

Will the activity develop or incorporate open-source software (either normatively or informatively) in the deliverables? No

6. Funding Requirements

Outline any contracted services or other expenses that are currently anticipated, beyond the basic support services provided to all IC activities. Indicate how those funds are expected to be obtained (e.g., through participant fees, sponsorships, government, or other grants, etc.). Activities needing substantial funding may require additional reviews and approvals beyond ICCom.

No funding is envisioned for this project, except to facilitate face-to-face meetings on an as-needed basis. Funds would optimally be attained through internal IEEE grants or through registration for in-person activities.

7. Management and Procedures

7.1 Activity Oversight Committee

Indicate whether an IEEE Standards Committee or Standards Development Working Group has agreed to oversee this activity and its procedures.

Has an IEEE Standards Committee or Standards Development Working Group agreed to oversee this activity? No.

If yes, indicate the IEEE committee's name and its chair's contact information.

IEEE Committee Name:
Chair's Name:
Chair's Email Address:

IEEE collects personal data on this form, which is made publicly available, to allow communication by materially interested parties and with the Activity Oversight Committee and Activity officers who are responsible for IEEE work items.

7.2 Activity Management

If no Activity Oversight Committee has been identified in 7.1 above, indicate how this activity will manage itself on a day-to-day basis (e.g., executive committee, officers, etc.).

This activity will be managed jointly by the standards committees listed in 8.4, with the appointed Chairs of each (as defined in their respective Policies and Procedures document) serving as *ex officio* members of the Industry Connections Activities. These standards committees will provide technical support to select the Chair, Vice-Chair, Secretary, and (as needed) Treasurer, and aid in the organization of as-needed in-person meetings.

7.3 Procedures

Indicate what documented procedures will be used to guide the operations of this activity; either (a) modified baseline *Industry Connections Activity Policies and Procedures* (entity, individual), (b) *Abridged Industry Connections Activity Policies and Procedures* (entity, individual), (c) Standards Committee policies and

procedures accepted by the IEEE SA Standards Board, or (d) Working Group policies and procedures accepted by the Working Group's Standards Committee. If option (a) is chosen, then ICCom review and approval of the P&P is required. If option (c) or (d) is chosen, then ICCom approval of the use of the P&P is required.

A) Modified baseline

8. Participants

8.1 Stakeholder Communities

Indicate the stakeholder communities (the types of companies or other entities, or the different groups of individuals) that are expected to be interested in this IC activity and will be invited to participate.

Representatives of quantum material suppliers, device and precision measuring equipment manufacturers, solution providers over quantum computers, quantum computing simulator developers, quantum communication protocol implementers, government defense and technologic innovation offices, and regulators.

8.2 Expected Number of Participants

Indicate the approximate number of entities (if entity-based) or individuals (if individual-based) expected to be actively involved in this activity.

60, or about 15 members per technological pillar

8.3 Initial Participants

Provide a few of the entities or individuals that will be participating from the outset. It is recommended there be at least three initial participants for an entity-based activity, or five initial participants (each with a different affiliation) for an individual-based activity.

Use the following table for an individual-based activity:

Individual Name	Employer	Affiliation
Manjunath Ramachandra	Wipro Ltd	Wipro Ltd
Vaibhav Pratap	Centre for Development of Advanced Computing, India	C DAC
Jerry Gamble	QEDC	QEDC
Reena Dayal	Quantum Ecosystems Technology Council of India	QETCI
Soumya Das	TU/e Netherlands	The Eindhoven University of Technology
Catherine Lefebvre	Pasqal	Pasqal
Blaise Vignon	Alice&Bob	Alice&Bob
Stephen Bush	GE	GE
Other IEEE Committees that this group will establish liaisons with (Tyler Jaynes, Edward Au, Bruce Kraemer)		

8.4 Activity Supporter/Partner

Indicate whether an IEEE committee (including IEEE Societies and Technical Councils), other than the Oversight Committee, has agreed to participate or support this activity. Support may include, but is not limited to, financial support, marketing support and other ways to help the Activity complete its deliverables.

Has an IEEE Committee, other than the Oversight Committee, agreed to support this activity? Yes

If yes, indicate the IEEE committee's name and its chair's contact information.

IEEE Committee Name: Nanotechnology Council Standards Committee (NTC/SC)
Chair's Name: Tyler L. Jaynes
Chair's Email Address: tyler.l.jaynes@ieee.org

IEEE Committee Name: Computer Society Standards Activities Board (C/SAB)
Chair's Name: Edward Au
Chair's Email Address: edward.ks.au@gmail.com

Email confirmation was received from NTS/SC and C/SAB to support this proposed activity