A Response to “Request for Information on Quantum Information Science and the Needs of U.S. Industry”

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Presented by: -

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Introduction

Lockheed Martin is pleased to provide this response to the Request for Information (RFI) released by NIST on 08 April 2015 seeking feedback on Quantum Information Science (QIS) and the needs of US Industry.[1]

At Lockheed Martin, we view QIS as a “game changer” for the Corporation’s continued ability to design and deliver increasingly complex integrated systems, while reducing cost and increasing performance. We anticipate applications of such technologies ranging from machine learning for cyber security in the banking industry, to enhanced resolution remote sensing, to ultra-secure communication, to big data applications in genomics. To this end, we are actively working to exploit new paradigms in computing, sensing, and communication so our scientists and engineers can create innovative answers to our customers’ hardest problems.

Our investment in quantum research and development (R&D) spans multiple technical approaches, both customer-funded and internally-funded. To supplement internal R&D activities, we work in concert with a number of University and small business partners in the US, UK, Canada, Australia, New Zealand and elsewhere. In the UK, this includes a strategic five-year partnership with the London Centre for Nanotechnology[2], as well as a multi-year cooperative investment at the University of Oxford.

We also have experience partnering with major academic institutions to form and host larger centers of excellence. In 2011, we established the USC-Lockheed Martin Quantum Computing Center[3] at the University of Southern California’s Information Sciences Institute (Marina Del Rey, CA) to host and operate a D-Wave superconducting quantum annealing platform. Then, in 2014, we expanded our engagement with the University of Maryland (College Park, MD), forming the UMD-Lockheed Martin Quantum Engineering Center[4] to design, build, and test an ion-trap based quantum information processor.

Lockheed Martin supports and acknowledges the efforts of NIST and the Interagency Working Group on Quantum Information Science in reaching out to the industrial community as an element to support the development and coordination of US Government policies, programs, and budgets that advance US competitiveness in QIS.

The following sections provide our perspective on the questions posed in the RFI call.

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[1] https://federalregister.gov/a/2015-08011
[2] http://www.lockheedmartin.com/uk/news/press-releases/2012-press-releases/new-research-partnership-launched-into-quantum-and-nanotechnolog.html
[3] http://www.isi.edu/research_groups/quantum_computing/home
[4] http://www.lockheedmartin.com/us/news/press-releases/2014/march/lm-university-of-maryland-develop-quantum-computer.html

Barriers

Funding levels and mechanisms, technology, dissemination of information, and technology transfer are some of the potential barriers to adoption of QIS technology.

What do you see as the greatest barriers to advancing important near-term and future applications of QIS? What should be done to address these barriers?

- Experimental advances in QIS typically focus on the functional unit level. While appropriate as proof-of-principle demonstrations, such achievements often lack the robustness of design and practicality of interface to be straightforwardly utilized and expanded upon by those not directly involved in their construction. Systems engineering, in contrast, focuses intensely on ensuring all pieces work together to achieve the objectives of the whole within a relevant context. More methods are needed to support the integration of QIS approaches into the existing application infrastructure.

- Unpredictable funding or breaks in program support allow key industry staff to be siphoned off to other projects. A coordinated and sustained activity at the Federal level to provide a focused effort with a dedicated investment is needed to climb the Technology Readiness Level (TRL) ladder in QIS-enabled applications.

- The industry technologists and system architects who best understand the real-world requirements and application drivers for small-scale sub-systems are less likely to have a QIS-aware background and skillset. The field needs support for accredited Master's level programs aimed at providing working engineers, computer scientists and similar with a solid grounding in QIS concepts.

- Other countries are investing in coordinated national programs aimed at QIS and quantum technology development (e.g. the UK[5], Canada[6], and Australia[7]). More international cooperation should be cultivated to allow all parties to benefit from sharing of pre-competitive research and opportunities for investment as technologies mature.

- Historically, the details and technological "know-how" in cutting edge experiments (i.e. elements of implementation apart from the science itself) have diffused slowly from university to industry, often dependent on the flux of individuals as they move

[5] https://www.epsrc.ac.uk/research/ourportfolio/themes/quantumtech/
[6] https://uwaterloo.ca/institute-for-quantum-computing/
[7] http://www.cqc2t.org/

through their careers. While still an indispensable method of knowledge transfer, greater agility is needed to address new opportunities at a quickened pace. For instance, more publications aimed at engineers are needed to introduce the practical details of QIS-enabled implementations within a context of traditional design, analysis, and test.

Workforce Needs

Addressing opportunities in QIS and barriers to applications requires a workforce spanning many disciplines, ranging from computer science and information theory to atomic scale manipulation of materials, and possessing a range of knowledge and skills.

What knowledge and skills are most important for a workforce capable of addressing the opportunities and barriers?

- Solid grounding in the fundamentals (Physics, Mathematics, Computer Science, Electrical Engineering) as well as a grasp of quantum mechanics (two-level systems, harmonic oscillators, rotations and angular momentum, avoided crossings, projective measurement, interaction picture, etc.)
- Broader perspectives gained through greater exposure of QIS students to a variety of technical disciplines (within academia) and across different business areas (within large and small industry)
- Facility and comfort in adapting to effectively communicate with technical colleagues who are non-experts in QIS
- Experience with systems design, analysis, documentation, and integration
- Understanding of the requirements drivers for compliance with standards and regulations
- Appreciation of intellectual property practices and rationales

In what areas is the current workforce strong, and in what areas is it weak?

- The US boasts an exceptional capability in both condensed matter (CM) and atomic, molecular, and optical (AMO) physics programs, including both university and national laboratories
- The relatively small number of US industry organizations active in QIS presents a challenge in attracting and supporting innovators in the field. While the industry workforce is strong in the engineering disciplines (systems, electrical, mechanical, software, etc.), the industry workforce is still weak (measured in *quantity* of employees) trained in quantum information science.

- The industry workforce is even weaker in people with dual skill sets in both engineering and quantum information science. In particular, the industry workforce needs more employees with co-training in both systems engineering and quantum information science.

What are the best mechanisms for equipping workers with the needed knowledge and skills?

- Availability of accredited Master's-level programs aimed at providing working engineers, computer scientists, and other technical employees with a solid grounding in QIS concepts
- Support for cooperative academic-industry development programs for design and integration of prototype QIS systems (i.e. beyond proof-of-principle functional units, but not at the scale of integrated commercial systems)
- More opportunities for secondment of industry staff at universities and national laboratories with strong QIS programs (including visiting professorships / visiting researcher status)
- Greater visibility of industry R&D culture to university-based QIS researchers, including via summer studentships, invited talks for faculty, co-hosting of workshops, etc.