Submission to

Quantum Information Science Industry RFI

of the National Institute of Standards and Technology, U.S. Department of Commerce

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(1) Opportunities

Quantum information science already finds broad applications as quantum sensors and transducers. However most of these today involve only a single qubit and modest coherence. There is a tremendous opportunity to integrate a small quantum processor for improved robustness, selectivity and sensitivity. In particular there are opportunities to develop sensors from hybrid structures, combining sensitive qubits with resilient ones.

Very little is known regarding coherent control, the efficiency limits and how to most effectively implement feedback schemes. Improvement in this area would benefit all of quantum information science (QIS) for small quantum processors in the short term and lay the groundwork for larger quantum processors.

The experimental community is working towards small processors with complexities of around 100 physical (i.e., not logical) qubits.. These may find application exploring the physics of quantum materials. There needs to be more concrete proposals of how to best use such processors and what questions in condensed matter physics are well suited to this approach.

Materials remain a very dynamic field and one that can have a tremendous impact on the development of quantum processors. The development of materials should be a more integrated activity in QIS.

(2) Market Areas and Applications

The emerging market is one of transducers and sensors. The applications are to medicine (non-invasive glucose level monitoring in tissue, improved contrast in imaging, improved S/N in imaging, measures of reactive oxygen in tissue, etc.); environmental monitoring (methane mapping); navigation (gyroscopes and clocks); remote sensing (small magnetic fields); nanoscale sensing and transduction.

There are also important areas for quantum materials and control to achieve an improved classical outcome, perhaps the most important being spintronics.

(3) Barriers

Funding levels are always a challenge, but in our opinion the greatest challenges are that the funding chases the flavor of the day. The funding should support all modalities of quantum processors and in particular new and hybrid approaches. There will not be one technology from which all quantum devices are made.

There are opportunities to use some funding to support translational research that aims to connect quantum technologies in academic settings to R&D labs.

(4) Workforce Needs

The QIS workforce needs to be even broader and better connected than one thinks. The fields of control theory, materials science and information theory need to be layered with a depth of knowledge regarding quantum mechanics and condensed matter physics. There are important gaps that are left unfilled. While the QIS and condensed matter theorists each talk about multi-body physics, they do not effectively share ideas. Unfortunately there remains another gap to the experiments: we need a concerted effort to connect these fields. In the area of control there needs to be a program to develop the foundations. Today we have a reasonable foundation in open quantum systems of small Hilbert spaces, but it is rarely part of the curriculum in physics departments. We lack a useful theory to apply to large systems. Developing these should be a priority not only at the physics but also at the engineering level.

There is no one way of accomplishing this training, but we need new textbooks, new teaching laboratories, and probably a new language to better connect QIS to physics and engineering.