CRADA Final Report Form

Date: December 1, 2020

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CRADA AWD No.: AWD00003301 **CRADA FP No.:** FP00007654

LBNL Report Number: _____*(SPO to add)*

OSTI Number: _____ *(SPO to add)*

1. Parties: (Identify Parties to the CRADA)
   LBNL and Bleximo

2. Title of the Project: Quantum hardware accelerators for real-world applications

3. Summary of the specific research and project accomplishments:
   (Were key major goals of the CRADA achieved?)
   Note: Final Reports and Forms containing Protected CRADA Information are to be emailed directly to the SPO close out requestor, along with a confirmation of the public release date. Do not submit via eSRA. Also, please do not include any Proprietary Information (defined below) in CRADA Final Reports and Forms.*

   Main accomplishments during CRADA include:

   - Designed and tested scalable microwave packaging solutions for superconducting quantum processors (between 8 and 40 lines), which minimize parasiting cross-talk, improve signal integrity, and extend coherence in multi-qubit circuits;
   - Built and experimentally tested microwave packaging solutions on 8-qubit processors with next-neighbor qubit coupling. First A/B tests demonstrated one packaging solution improving the coherence time of processors by ~3x; additiomnal tests are underway;
   - Designed chip architecture and testing protocols for high-precision cryogenic testing of non-qubit elements of superconducting processors (filters, resonators, etc.);
   - Designed and simulated performance of several processor architectures for quantum chemistry applications, factoring in experimentally available qubit coherence times and realistic noise models;
   - Designed and simulated performance of all elementary blocks (qubits, filters, resonators, etc.) for building processors with varying architectures; started experimental tests of these elements to validate simulated models;

- Designed and tested off-chip filtering solutions for improved qubit isolation, including bandpass all-metal combline filters and microfabricated low-pass reflectionless filters (publication in preparation);
- Experimentally tested FPGA chips in cryogenic conditions for the advanced low-noise control solution (publication in preparation).

4. Deliverables:

Deliverables met	Party (LBNL, Participant, Both)	Delivered to Other Party?
Project mentorship relative to Cyclotron Road program objectives.	LBNL	complete
Quarterly updates on progress against this Statement of Work will be presented to the cognizant LEEP Program Manager.	Participant	complete
A final report will be due upon conclusion of CRADA, including a list of intellectual property arising under this SOW	Participant	complete

5. Identify (list below) and attach all publications or presentations at conferences directly related to the CRADA:

   Publications in preparation:

   - Low-pass reflectionless filters for flux-tunable qubit control;
   - Performance of FPGA chips in cryogenic conditions for the advanced low-noise superconducting qubit control.

6. List of Subject Inventions and software developed under the CRADA: (Please provide identifying numbers or other information.)

Nothing to disclose

7. A final abstract suitable for public release:
   (Very brief description of the project and accomplishments without inclusion of any proprietary information or protected CRADA information.)

The research Bleximo Corp. conducted at Cyclotron Road was focused on developing application-specific superconducting quantum processors for high-value problems in quantum chemistry, in particular, calculating chemical binding energy in biomolecular systems, such as

protein-ligand complexes, with chemical precision. Several candidate architectures were identified through simulations, which included experimentally-proven quantum bit architectures and realistic noise and cross-talk models in multi-qubit superconducting quantum processors.

8. Benefits to DOE, LBNL, Participant and/or the U.S. economy.

   This project was part of the Cyclotron Road Program, which advances the DOE's mission and strengthens U.S. economic competitiveness, energy security, and resource sustainability for the U.S. Taxpayer by:

   - Enabling and supporting top technology innovators (e.g. Participant) in pursuit of breakthrough advanced energy materials and manufacturing technologies that are aligned with DOE's mission;
   - Strengthening the core scientific capabilities of the national lab by connecting Berkeley Lab scientists to a dynamic network of industry innovators, bridging an important link between fundamental science and real-world technology development challenges;
   - Encouraging private sector collaboration with the national lab and investment in critical clean energy technologies; and
   - Demonstrating a new model for translating hard science-based clean energy technologies from lab to market that can be replicated at national labs and academic R&D centers across the nation.

9. Financial Contributions to the CRADA:

DOE Funding to LBNL	$100K
Participant Funding to LBNL	$0
Participant In-Kind Contribution Value	$50K
Total of all Contributions	$150K

** "Proprietary Information" means information, including data, which is developed at private expense outside of this CRADA, is marked as Proprietary Information, and embodies (i) trade secrets or (ii) commercial or financial information which is privileged or confidential under the Freedom of Information Act (5 U.S.C. 552 (b)(4)).*