

U.S. ARMY RESEARCH OFFICE
BROAD AGENCY ANNOUNCEMENT

W911NF-10-R-0007



Development of Quantum Computing Technology

This publication constitutes a Broad Agency Announcement (BAA) and sets forth basic research areas of interest in the area of quantum computing. This BAA is issued under the provisions of Federal Acquisition Regulation (FAR) 6.102(d)(2) and Department of Defense Grant and Agreement Regulations (DODGARS) 22.315.

OVERVIEW INFORMATION

Agency Name: U.S. Army Research Office, Physics Division, P.O. Box 12211, Research Triangle Park, NC 27709-2211

Issuing Acquisition Office: U.S. Army RDECOM Contracting Center, RTP Contracting Division, P.O. Box 12211, Research Triangle Park, NC 27709-2211

Research Opportunity Title: Development of Quantum Computing Technology

Announcement Type and Date: Initial Announcement – April 2010

Research Opportunity Number: W911NF-10-R-0007

Catalog of Federal Domestic Assistance (CFDA) Number and Title: 12.431 – Basic Scientific Research

Response Dates:

White Papers: No later than 4:00 PM Eastern Time on Monday, 24 May 2010.

Proposals: No later than 4:00 PM Eastern Time on Monday, 12 July 2010.

I. RESEARCH OPPORTUNITY DESCRIPTION

The U.S. Army Research Office (ARO) together with the National Security Agency (NSA) is soliciting proposals for basic and applied research to advance quantum computing technology. Research areas of particular interest include:

1. Robust solid-state qubits and related technologies;
2. Short-to-medium-range quantum information transfer in solid-state systems;
3. Ideas, methods, and procedures for the verification/validation of quantum computing components.

Area of Interest 1: Robust Solid-State Qubits and Related Technologies

Qubits are the foundation of both memory and processing in quantum information systems. In this area of interest, we seek proposals that address the development of single- and few-qubit solid-state devices. Also considered will be proposals for major advances in related supporting technologies. Proposed research may be experimental, theoretical, or both, and should address *at least one*, and preferably several, of the following goals:

- Extending the state-of-the-art in solid-state qubits in relation to key metrics of qubit performance including, for example, reproducibility, quantum coherence time, gate operation speed and fidelity, operating temperature, noise level, and/or materials/fabrication complexity.
- Novel ideas for robust solid-state qubit design or fabrication. Examples could include, but are not limited to: topology or symmetry protected qubits, new material systems, new ways of organizing or addressing qubits, and/or new paradigms of quantum computation with imperfect components. (Anyonic or topological insulator proposals are not of interest.)
- Theoretical analysis of solid-state qubit materials, devices, or systems to better quantify, predict, or improve relevant metrics for quantum computing performance.
- Development of specific and revolutionary supporting technologies for solid-state qubits. Potential examples are materials science, readout devices or systems, amplifiers, or relevant electronics.

Proposals submitted to this Area of Interest should include a clear statement of the goals addressed, as well as the quantitative benefits of the proposed research compared to the state-of-the-art.

Area of Interest 2: Quantum Information Transfer

For quantum information processing systems, it is often preferable to have a means of sending quantum information beyond nearest-neighbor without large overhead costs (for example, without doing a large number of swap gates). This area of interest seeks innovative approaches to transfer quantum information in solid-state systems, including on-chip transfer, off-chip transfer, or both. Selected proposals will greatly advance the current state-of-the-art in relevant performance metrics for a specific solid-state qubit

implementation. The following performance metrics should be addressed: overhead (in time, number of operations, or complexity), speed of transfer, fidelity, and footprint. Proposals submitted to this Area of Interest may be theoretical, experimental, or both.

Area of Interest 3: Verification/Validation and Analysis of Quantum Computing Components

A challenge for quantum information processing systems, especially as they increase in size, is the efficient and accurate verification/validation of their performance for the task at hand. In this third area of interest innovative proposals are sought to address the verification/validation of quantum information processor components. Possible topics could include, but are not limited to: advances/alternatives to quantum tomography; methods for extracting fidelity of gate or computation success; and methods or procedures for verifying complex quantum computations that cannot be classically simulated. Proposals may be theoretical, experimental, or both. Experimental implementations of innovative ideas for verification/validation are encouraged.

While all innovative proposals relevant to the advancement of quantum computing technology will be considered, there is little interest in quantum algorithms, foundations of quantum mechanics, or new types of qubits that are not convincingly competitive with existing qubit designs. White papers and proposals submitted for topics in these areas are discouraged since they have little chance of being funded.

Proposed efforts may consist of teams or single performers.

II. AWARD INFORMATION

Awards made under this BAA may be in the form of contracts or grants and are subject to the availability of appropriations. Proposals should be written to include a base period of one year plus two one-year option periods. Projects must have clear goals for each year. Funding for the option years will be contingent upon satisfactory performance of the base period and the availability of funds. Most proposals will request funding in the range of \$200K to \$1M per year. Multiple awards under the BAA are anticipated.

III. ELIGIBILITY INFORMATION

A. Eligible Applicants:

Proposals may be submitted by degree-granting universities (foreign and domestic), nonprofit organizations, or industrial concerns (large and small businesses). Proposals are encouraged from historically black colleges and universities and minority-serving institutions of higher education defined under Covered Educational Institution at 10 U.S.C. § 2362 (e). However, no funds are specifically allocated for HBCU/MI participation.

B. Cost Sharing or Matching:

There is no required cost sharing, matching, or cost participation to be eligible under this BAA.

C. Dun and Bradstreet Universal Numbering System (DUNS) Number and Central Contractor Registration (CCR):

Applicants are required to (i) be registered in the CCR prior to submitting an application; (ii) provide a valid DUNS number in the application; and (iii) continue to maintain an active CCR registration with current information at all times during an active Federal Award and through final payment. The CCR may be accessed at <http://www.ccr.gov>. Assistance with registration is available by phone at 1-866-606-8220.

D. Other:

Federal laboratories, Federally Funded Research and Development Centers, and academic institutions that are federal government organizations (e.g., Naval Postgraduate School) may submit to the federal program for support, but are not eligible to receive funding awarded through this BAA. These organizations are encouraged to contact QC_Proposals@lps.umd.edu for information on how to submit to the internal research program.

IV. APPLICATION AND SUBMISSION INFORMATION

This BAA may be accessed from the FedBizOpps, Grants.gov and the ARO website <http://www.arl.army.mil/www/default.cfm?Action=6&Page=8>. Amendments to this BAA will be posted to these websites when they occur. Interested parties are encouraged to periodically check these websites for updates and amendments.

A. Application and Submission Process:

The application process is in two stages as follows:

Stage 1 White Papers – Prospective offerors are strongly encouraged to submit white papers to minimize the labor and cost associated with the production of detailed proposals that have very little chance of being selected for funding. Based on assessment of the White Papers, e-mail feedback will be provided to the offerors to encourage or discourage submission of full proposals. Regardless of the Government response to a White Paper, offerors may submit a full proposal.

Stage 2 Full Proposals – Offerors should submit full proposals in accordance with the requirements set forth in this BAA.

NOTE: All proposals submitted under the terms and conditions cited in this BAA will be reviewed regardless of the feedback provided on a White Paper submission(s). If offerors

have not submitted White Papers under Stage 1 of the BAA, offerors may still submit full proposals for consideration for funding. Full proposals must be submitted in order for the offeror to receive consideration for funding.

B. Submission of White Papers:

White Paper Format and Content:

White Papers must be submitted electronically to whitepapers@arl.army.mil in the following format:

- Single MSWord or pdf formatted file as an email attachment. The email subject line should contain the following: **W911NF-10-R-0007 White Paper.**
- Page Size – 8½ x 11 inches (when printed)
- Margins – 1 inch
- Spacing – double
- Font – No smaller than Times New Roman, 12 point
- Number of Pages – no more than seven (7) single-sided pages. White Papers exceeding the page limit may not be evaluated.

White Papers must contain the following:

- Title page. The title page should be labeled “Proposal White Paper” and should include the BAA number, proposed title, Principal Investigator (PI) with telephone number and email address, and an executive summary. (Not to exceed one page.)
- Expected expenditures and justifications. (Not to exceed one page.)
- Curriculum vitae sketches. (Not to exceed one page.)
- Technical portion including all references and figures. Introduce the problem to be addressed, briefly survey related work, identify key obstacles, describe how the proposed research improves current state-of-the-art, outline the proposed solution and well-defined objective, outline the yearly research plan with milestones, and state the impact if successful. (Not to exceed four pages.)

C. Submission of Full Proposals:

Full proposals must be submitted electronically through the Grants.gov portal (<http://www.grants.gov>). Full proposals sent by mail, courier, fax, or email will not be considered.

Registration Requirements for Grants.gov (applies to all offerors):

There are several one-time actions your organization must complete in order to submit applications through Grants.gov (e.g., obtain a Dun and Bradstreet Data Universal Numbering System (DUNS) number, register with the Central Contract Registry (CCR), register with the credential provider, register with Grants.gov and obtain approval for an Authorized Organization Representative (AOR) to submit applications on behalf of the organization). Go to http://www.Grants.gov/applicants/get_registered.jsp for further information. Use the Grants.gov Organization Registration Checklist, which may be

accessed at <http://www.Grants.gov/assets/OrganizationRegCheck.pdf> to guide you through the process.

Questions: Questions relating to the registration process, system requirements, how an application form works, or the submittal process should be directed to Grants.gov at 1-800-518-4726 or support@grants.gov.

Note: In order to view, complete, and submit an application package, you may need to download the appropriate software packages. Go to http://www.Grants.gov/applicants/apply_for_grants.jsp for further information.

Content and Format of Application:

Application forms and instructions are available at Grants.gov. To access these materials, go to <http://www.grants.gov>, select “Apply for Grants,” and then select “Download a Grant Application Package.” Enter CFDA for Basic Scientific Research, 12.431, or the funding opportunity number, W911NF-10-R-0007. Follow the prompts to download the appropriate application package.

Form: SF 424 (R&R) – Application for Federal Assistance (Mandatory):

Complete all required fields in accordance with the pop-up instructions on the form. Authorized Organization Representative (AOR) usernames and passwords serve as “electronic signatures” when your organization submits applications through Grants.gov. By using the SF 424 (R&R), proposers are providing the certification required by 32 CFR Part 28 regarding lobbying as contained in Section VI B.

The following formatting rules apply for file attachments:

- Page Size – 8.5 x 11 inches (when printed)
- Margins – 1 inch
- Spacing – single
- Font – No smaller than Times New Roman, 12 point

FORM: Research & Related Senior/Key Person Profile (Mandatory):

Complete the requested information for the Principal Investigator (PI) and each key Co-investigator. Attach biographical sketch including relevant publications where indicated for the PI and Co-investigators.

Attach statement of current and pending support where indicated for the PI and Co-investigators. The statement should include the project title and brief description, source of support, award amount, period of performance, and breakdown of the time required of the PI and other senior personnel.

FORM: Research & Related Other Project Information (Mandatory):

Complete questions 1 through 6 and attach files. Files must comply with the following instructions:

Project Summary/Abstract (Field 7) (200 words or less):

Provide a concise description of the proposed research.

Project Narrative (Field 8) (not to exceed 30 pages):

Introduce the problem to be addressed, survey related work, identify key obstacles, describe how the proposed research improves current state-of-the-art, outline the proposed solution and well-defined objective, detail the yearly research plan with milestones, and analyze the impact if successful. Offerors should not feel compelled to use the entire page allotment. All pages should be numbered consecutively.

Bibliography & References Cited (Field 9) (no page limitation):

Provide a bibliography of pertinent literature. Citations must be complete including full name of author(s), title, and location in literature.

Facilities and Other Resources (Field 10) (no page limitation): Describe facilities available for performing the proposed research and any additional facilities or equipment the organization proposes to acquire at its own expense.

Equipment (Field 11) (no page limitation):

Provide a rationale for each item of equipment requested in the budget and how this equipment will contribute to the goals of the proposal.

Other Attachments (Field 12) (no page limitation):

Attach ARO Form 52A, Protection of Proprietary Information During Evaluation, and After Award/Statement of Disclosure Preference. This form may be accessed at <http://www.aro.army.mil/forms/forms2.htm> under “Forms-Broad Agency /Announcements (BAA),” and completed and saved as an Adobe PDF.

FORM: Research & Related Budget (Mandatory):

Complete Sections A through J and attach a budget justification at Section K. The estimated project costs must be shown in total as well as broken down to show cost elements for each year of the program. The budget justification should provide additional data (not included in Sections A through J) by element of cost, sufficient to meet the guidance provided below and ensure meaningful evaluation.

Salary Costs:

For all employees/labor categories, indicate the amount of time being charged to the proposed project (e.g., number of months) and show resulting costs based on current or projected salary and fringe benefits.

Equipment:

Describe any equipment to be acquired and the basis of cost estimates. Costs should be based on recent quotations from manufacturers or distributors.

Travel:

Estimate the required amount of travel and state its relationship to the research. List the proposed destinations and basis of cost estimates. Offerors should budget accordingly for an annual review meeting under this BAA. Participation by the PI and key research personnel is mandatory.

Participant/Trainee Support Costs:

Estimate tuition/fees/health insurance for students.

Other Direct Costs:**Materials and Supplies:**

Estimate costs of materials and supplies. List types of materials needed and costs. Provide basis for cost estimates.

Publication Costs:

Estimate the costs of publishing and reporting research results.

Consultant Services:

State the planned daily consultant fee and travel expenses, the nature of the consulting effort, and the reason consultants are required to complete the effort.

Subaward Costs:

Support the estimate of subaward work by indicating the specific items or portion of the work to be subawarded, type of subaward anticipated, name of subawardee, and a detailed budget for each. Budgets should contain the same level of detail as required on the R&R Budget form.

Subaward budgets must be in PDF format and attached to the **R&R Subaward Budget Attachment(s) Form**.

Equipment Rental/User Fees:

Estimate anticipated direct costs such as rental for computers or other equipment and facility usage fees. Unusual or expensive items should be fully justified.

Indirect Costs (Overhead, General and Administrative, and Other):

Provide the most recent rates, dates of negotiations, the base(s) and period to which the rates apply, and a statement identifying whether the proposed rates are provisional or fixed. If the rates have been negotiated by a Government agency, state when and by which agency. Include a copy of any current indirect rate agreement or provide a URL if this document is available from the Internet.

Fee:

State the fixed fee, if any, which a commercial organization proposes to assess the research project.

FORM: Disclosure of Lobbying Activities (Standard Form LLL) (Optional):

If applicable, this form must be completed. This form is applicable if any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the application for a grant under this BAA.

Failure to provide the requested information or exceed page limits may render the proposal non-responsive, and the proposal may not be evaluated.

Separate attachments, such as institutional brochures or reprints, cannot be considered.

D. Submission Dates and Times:**White Papers:**

White Papers must be successfully received by **4:00 PM Eastern Time on Monday, 24 May 2010**. White Papers received after the deadline will not be reviewed. Feedback on the White Papers will be e-mailed directly to the proposed principal investigators by **Friday, 11 June 2010**.

Proposals:

Proposals must be received no later than **4:00 PM Eastern Time on Monday, 12 July 2010**.

Proposal Receipt Notices:

After a proposal is submitted to Grants.gov, the Authorized Organization Representative (AOR) will receive a confirmation screen as well as three e-mails from Grants.gov. The first two e-mails should be received within 24 to 48 hours after submission. The first e-mail will confirm receipt of the application by the grants.gov system, and the second will indicate that the application has either been successfully validated by the system prior to transmission to the grantor agency or has been rejected due to errors. A third e-mail should be received once the agency has confirmed receipt of the proposal. The document, Tracking Your Application Package, located at <http://www.grants.gov/assets/TrackingYourApplicationPackage.pdf> explains this process.

It is highly recommended that grant applications be submitted 24-48 hours prior to the due date and time to avoid delays due, for example, to high system usage immediately prior to the due date and time and to allow time to ensure successful validation.

Late Submission of Proposals:

Any proposal submitted through Grants.gov where the date and time of submission (as recorded in the first e-mail from Grants.gov) is after the specified deadline for proposal submission, will be considered late and will not be evaluated unless the Grants.gov website was not operational on the due date and was unable to receive the proposal submission. If this occurs, the time specified for the receipt of proposals through Grants.gov will be extended to the same time of day specified in this BAA on the first workday on which the Grants.gov website is operational.

V PROPOSAL REVIEW INFORMATION

A. Criteria:

Proposals submitted in response to this BAA will be evaluated on two main criteria, both of equal weight:

1. Scientific and technical merits of the proposed research; and
2. Potential contribution of the research to advance quantum computing technology.

Other evaluation criteria, of lesser importance, but weighted equal to each other include:

1. Experience and qualifications of the principal investigator, other key research personnel, and the institution sponsoring the proposal; and
2. The realism and reasonableness of cost.

NOTE: Cost sharing will not be considered in the evaluation.

B. Review and Selection Process:

The proposal selection process will be conducted based upon a technical review by a panel of government scientists according to the evaluation criteria specified above.

VI. AWARD ADMINISTRATION INFORMATION

A. Award Notices:

Notification of selection of proposals will be e-mailed by ARO to successful offerors on or about **Friday, 6 August 2010**. Unsuccessful offerors will be notified shortly thereafter.

The notification of selection e-mail must not be regarded as an authorization to commit or expend funds. The Government is not obligated to provide any funding until a Government Grants/Contracting Officer signs the grant or contract award document.

Offerors whose proposals are recommended for negotiation of award will be contacted by a Contract/Grant Specialist to discuss additional information required for award. This may include representations and certifications, revised budgets or budget explanations, certificate of current cost or pricing data, small business subcontracting plan, and other information as applicable to the proposed award. The award start date will be determined at this time. A contract or grant document signed by the Government Contracting/Grants Officer is the only authorizing award document.

B. Administrative and National Policy Requirements:

Certification Required for Grant Awards:

The certification at Appendix A to 32 CFR Part 28 regarding lobbying is the only certification required at the time of proposal submission for a grant award. The certification is as follows:

“By signing and submitting a proposal that may result in the award of a grant exceeding \$100,000.00, the prospective awardee is certifying, to the best of his or her knowledge and belief, that:

(a) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of an agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(b) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, “Disclosure Form to Report Lobbying,” in accordance with its instructions.

(c) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, and subgrants, and contracts under grants, and loans, or cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty or not less than \$10,000 and not more than \$100,000.00 for each such failure.”

Certifications Required for Contract Awards:

Certifications and representations shall be completed by successful offerors prior to award. Federal Acquisition Regulation (FAR) and Department of Defense FAR Supplement (DFARS) Online Representations and Certifications Application (ORCA) are at website <http://orca.bpn.gov>.

Export Control:

- a. The contractor shall comply with all U.S. export control laws and regulations, that may apply in the course of the research, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in the performance of this contract. In the absence of available license exemptions/exceptions, the Contractor shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports of (including deemed exports) hardware, technical data, and software, or for the provision of technical assistance.
- b. The Contractor shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of this contract, including instances where the work is to be performed on-site at any Government installation (whether in or outside the United States), where the foreign person will have access to export-controlled technologies, including technical data or software.
- c. The Contractor shall be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions/exceptions.
- d. The Contractor shall be responsible for ensuring that the provisions of this clause (and any required DFARS clause) apply to its subcontractors as applicable or required.

Employment Eligibility Verification: (for Contract Awards only):

Contracts awarded under this BAA will include FAR 52.222-54, Employment Eligibility Verification. Contractors must enroll as Federal Contractors in E-Verify and use E-Verify to verify employment eligibility of all employees assigned to the award.

C. Reporting Requirements:

Reporting requirements for contracts and grants awarded under this BAA will be as described in ARO Form 18 located at <http://www.aro.army.mil/forms/forms2.htm>. Additional reports (e.g., monthly status reports) will be specified in the award document.

D. Security:

Proposals must not include any information that has been identified as classified national security information under authorities established in Executive Order 12958, Classified National Security Information.

VII. Agency Contacts

The technical point of contact is Dr. T.R. Govindan, U.S. Army Research Office (ARO) Physics Division, email: tr.govindan@us.army.mil.

The administrative point of contact is Ms. Lida Barton, US Army RDECOM Contracting Center, RTP Contracting Division, phone: (919) 549-4266 e-mail: lida.barton@us.army.mil.

Comments or questions submitted should be concise and reference the relevant part and paragraph of the Broad Agency Announcement (BAA). Comments or questions should reference BAA # W911NF-10-R-0007 in the email subject line.