

Quantum and Biologically Inspired Computing (QuBIC)

Program Announcement

NSF 01-95

DIVISION OF EXPERIMENTAL AND INTEGRATIVE ACTIVITIES

FULL PROPOSAL DEADLINE(S) :

June 29, 2001 and First Monday in February each year thereafter.



NATIONAL SCIENCE FOUNDATION



The National Science Foundation promotes and advances scientific progress in the United States by competitively awarding grants and cooperative agreements for research and education in the sciences, mathematics, and engineering.

To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of awards, visit the NSF Web Site at:

<http://www.nsf.gov>

- **Location:** 4201 Wilson Blvd. Arlington, VA 22230
- **For General Information (NSF Information Center):** (703) 292-5111
- **TDD (for the hearing-impaired):** (703) 292-5090
- **To Order Publications or Forms:**
 - Send an e-mail to: pubs@nsf.gov
 - or telephone: (301) 947-2722
- **To Locate NSF Employees:** (703) 292-5111

SUMMARY OF PROGRAM REQUIREMENTS

GENERAL INFORMATION

Program Title: Quantum and Biologically Inspired Computing (QuBIC)

Synopsis of Program: The program will support interdisciplinary research to improve the fundamental capabilities of computer science by incorporating insights from either biological systems or quantum foundations or both. To achieve this improvement, fundamental research is needed towards the unification of information science across computer science, physics, biology, and engineering. Expanding efforts in interdisciplinary research areas that are at the interface of information science and technology with the fields of biology, chemistry, engineering, physics, and computer science will lead to better understanding in all areas of science. This will increase the ability to develop future information technologies that are very critical to the economy and society at the national and international level. Group proposals representing multiple disciplines will receive priority but single investigator proposals that are cross-disciplinary will also be considered.

Cognizant Program Officer(s):

- Mita Desai, Program Director, CISE/EIA, Rm 1160, telephone: (703)292-8980, e-mail: mdesai@nsf.gov.

Applicable Catalog of Federal Domestic Assistance (CFDA) Number(s):

- 47.070 --- Computer and Information Science and Engineering

ELIGIBILITY INFORMATION

- **Organization Limit:** None
- **PI Eligibility Limit:** None
- **Limit on Number of Proposals:** None

AWARD INFORMATION

- **Anticipated Type of Award:** Standard or Continuing Grant
- **Estimated Number of Awards:** Approximately 15
- **Anticipated Funding Amount:** Approximately \$5 Million; typical award size \$100,000-500,000 over three years.

PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

- **Full Proposals:** Standard Preparation Guidelines
 - Standard GPG Guidelines apply.

B. Budgetary Information

- **Cost Sharing Requirements:** Cost Sharing is not required.
- **Indirect Cost (F&A) Limitations:** Not Applicable.
- **Other Budgetary Limitations:** Not Applicable.

C. Deadline/Target Dates

- **Letters of Intent (optional):** None
- **Preliminary Proposals (optional):** None
- **Full Proposal Deadline Date(s):**

June 29, 2001 and First Monday in February each year thereafter.

D. FastLane Requirements

- **FastLane Submission:** Required
- **FastLane Contact(s):**
 - Helen A. Walston, Senior Program Assistant, Division of Experimental and Integrative Activities (CISE/EIA), telephone: (703)292-8980.

PROPOSAL REVIEW INFORMATION

- **Merit Review Criteria:** National Science Board approved criteria apply.

AWARD ADMINISTRATION INFORMATION

- **Award Conditions:** Standard NSF award conditions apply.
- **Reporting Requirements:** Standard NSF reporting requirements apply.

I. INTRODUCTION

The program will support interdisciplinary research to improve the fundamental capabilities of computer science by incorporating insights from either biological systems or quantum foundations or both. To achieve this improvement, fundamental research is needed towards the unification of information science across computer science, physics, biology, and engineering. Expanding efforts in interdisciplinary research areas that are at the interface of information science and technology with the fields of biology, chemistry, engineering, physics, and computer science will lead to better understanding in all areas of science. This will increase the ability to develop future information technologies that are very critical to the economy and society at the national and international level. Group proposals representing multiple disciplines will receive priority but single investigator proposals that are cross-disciplinary will also be considered.

QuBIC will build on prior NSF programs and workshops recommendations. On October 28-29, 1999 a workshop on Quantum Information Science- An Emerging Field of Interdisciplinary Research and Education in Science and Engineering was held at NSF; see <http://www.nsf.gov/cgi-bin/getpub?nsf00101> for report. A previous NSF Initiative on Learning and Intelligent Systems, later incorporated into Knowledge and Distributed Intelligence, included significant support for efforts to build functioning computer designs based on serious intellectual collaborations between technologists, neuroscientists and psychologists. The QuBIC program will build upon such past experience and workshops, in order to support a broader range of fundamental scientific research to develop and unify revolutionary concepts and designs relevant to computing, both analog and digital.

II. PROGRAM DESCRIPTION

The QuBIC program is seeking research proposals that will investigate and develop fundamental revolutionary concepts and phenomena. This program announcement is intended to facilitate new insights and understanding, drawing on several fields to stimulate research in the areas of quantum information science (QIS), and of biologically inspired computing -- ultimately leading to deeper unification of information sciences, quantum foundations and biology. Proposals in either area or across the two areas will be considered.

QIS includes quantum computers, quantum communication, and other quantum based approaches to processing and understanding information. This program will try to emphasize two more fundamental, long-term issues in QIS: (1) research which probes the physical foundations which are relevant not only to QIS but to other areas of future possible technology; (2) strategies to develop quantum computing principles for general-purpose computing and systems-level computing design, and special-purpose algorithms that transcend the limitations of special purpose algorithms now available for niche applications such as cryptography and number theory. Proposals aimed at these niche applications might be better submitted to other agencies with mission responsibility in these areas.

In physical foundations, the areas of interest include (but are not limited to) topics such as:

- Empirically-driven understanding of fundamental decoherence effects, particularly at low

temperatures

- Better operational understanding of measurement and temporal effects in measurements of entangled states of all kinds
- Better understanding of novel types of entanglement, such as double entanglement or positional entanglement or N2 entanglement
- Use of QIS experiments to address issues in the foundations of physics
- Developing a broad and general collection of quantum algorithms
- Extending concepts of information theory to the realm of quantum foundations and experiments
- Strategies to use stable attractors or self-stabilization effects to reduce error rate in QIS

In general-purpose computing and systems-level computing design, there is interest in topics such as (but not limited to):

- Quantum simulation of quantum systems (e.g. molecular modeling)
- Use of learning rather than programming to achieve general-purpose capability (e.g. quantum neural networks, including quantum associative memory and quantum-based stochastic search)
- Use of computer science theory to address broader ranges of computational tasks
- Concepts like quantum fast Fourier transforms and similar approaches to reach a large user base
- Novel approaches to fault tolerance and to managing the stochastic errors in quantum systems.

Biologically-inspired computing extracts the fundamental, general-purpose computational principles or algorithms from natural biological information processing systems (BIPS), and may help us both in replicating and understanding the capabilities of biological systems. At present, the BIPS with greatest promise for general-purpose computing are the bioinformatics (genomic/proteomic) system and the general-purpose learning capabilities of higher neural systems. However, other robust systems are also worthy of exploration, and will fall within the scope of this program, subject to the review criteria.

NSF already supports, in other programs, efforts in computational neuroscience, in bioinformatics, and in general-purpose computing. This program will focus on novel efforts, which build bridges between these areas that develop a more unified and powerful understanding than is possible within the scope of the individual disciplines.

More precisely, this program will focus on biologically-inspired research, which meets stringent standards of partnership between disciplines. For example, proposals will be considered which take such a crossdisciplinary approach to topics in bioinformatic or molecularly inspired computing. Biological systems may be used as a source of inspiration either for algorithmic design or for new types of hardware or both; however, the focus must be on general-purpose principles and capabilities, adaptable to a wide range of computational tasks, rooted in a strong intellectual contribution both from biological and informational science and technological disciplines. Naturally, in the analysis of molecular phenomena (either natural or artificial), the sophisticated use of quantum principles is also a factor.

This program would cover proposals which meet the goals of the preceding paragraph in topics including (but not limited to):

- Understanding of molecular properties at various scales
- Modeling of subcellular processes
- Modeling of the mechanisms whereby cells undergo phase changes
- Design and synthesis of DNA type molecules or protein structures for molecular electronics or memory
- Biosensors, devices, and systems to support empirical study of molecular information processing within cells
- Algorithms, simulations, and models based on complex molecular level processes
- Genetic mechanisms (like histones) used to strengthen the computational power of natural selection itself suggesting more adaptable variations of evolutionary computation
- Analysis and modeling of molecular information processing and structures as a system for decision making and control by the cell
- Hardware may include development of new materials, molecular electronics, molecular biosensors, biological computers, or associated fabrication by self-assembly.

This program will strive to develop revolutionary new insights, which of necessity must go beyond conventional wisdom and allow for a wide range of unproven possibilities. Therefore, explicit efforts will be made to allow for theories and approaches which provide plausible alternatives, even when reviewers and program directors agree that such alternatives have less than a fifty percent chance of being true in the end. For example, some researchers theorize that biological neurons include a molecular-based quantum associative memory capability in the cytoskeleton, which enhances the computational capability of a single neuron. The key research challenge for such minority views is to move as efficiently as possible towards enhancing their credibility if they should in fact be true, by devising and performing decisive experiments. In the case of the quantum neuron example, this program would give serious consideration to proposals to test such ideas, for example, by trying to train individual neurons on a chip to learn complex behaviors like the XOR or parity functions as a step towards answering questions about the quantum and molecular information processing within a cell. This is just one example, but it illustrates a more general strategy. In general, this program will include efforts to extract whatever could be learned from heresies and minority opinions, which have serious, coherent theoretical content.

III. ELIGIBILITY INFORMATION

The categories of proposers identified in the [Grant Proposal Guide](#) are eligible to submit proposals under this program announcement/solicitation.

IV. AWARD INFORMATION

Estimated program budget, number of awards and average award size/duration are subject to the availability of funds. Approximately \$5 Million will be available to fund approximately 15 standard or continuing grants. A typical QuBIC award will be in the range \$100,000 - \$500,000 per year for up to three years depending on the scope of the work proposed. However, smaller or larger awards will also be considered.

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Full Proposal:

Proposals submitted in response to this program announcement/solicitation should be prepared and submitted in accordance with the general guidelines contained in the NSF *Grant Proposal Guide* (GPG). The complete text of the GPG is available electronically on the NSF Web Site at: <http://www.nsf.gov/cgi-bin/getpub?nsf012>. Paper copies of the GPG may be obtained from the NSF Publications Clearinghouse, telephone (301) 947-2722 or by e-mail from pubs@nsf.gov.

Proposers are reminded to identify the program solicitation number (NSF 01-95) in the program announcement/solicitation block on the NSF Form 1207, *Cover Sheet For Proposal to the National Science Foundation*. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.

B. Budgetary Information

Cost sharing is not required in proposals submitted under this Program Announcement.

C. Deadline/Target Dates

Proposals must be submitted by the following date(s):

Full Proposals by 5:00 PM local time:

June 29, 2001 and First Monday in February each year thereafter.

D. FastLane Requirements

Proposers are required to prepare and submit all proposals for this Program Announcement through the FastLane system. Detailed instructions for proposal preparation and submission via FastLane are available at: <http://www.fastlane.nsf.gov/a1/newstan.htm>. For FastLane user support, call 1-800-673-6188.

Submission of Signed Cover Sheets. The signed copy of the proposal Cover Sheet (NSF Form 1207) must be postmarked (or contain a legible proof of mailing date assigned by the carrier) within five working days following proposal submission and be forwarded to the following address:

National Science Foundation
DIS – FastLane Cover Sheet
4201 Wilson Blvd.
Arlington, VA 22230

VI. PROPOSAL REVIEW INFORMATION

A. NSF Proposal Review Process

Reviews of proposals submitted to NSF are solicited from peers with expertise in the substantive area of the proposed research or education project. These reviewers are selected by Program Officers charged with the oversight of the review process. NSF invites the proposer to suggest at the time of submission, the names of appropriate or inappropriate reviewers. Care is taken to ensure that reviewers have no conflicts with the proposer. Special efforts are made to recruit reviewers from non-academic institutions, minority-serving institutions, or adjacent disciplines to that principally addressed in the proposal.

Proposals will be reviewed against the following general review criteria established by the National Science Board. Following each criterion are potential considerations that the reviewer may employ in the evaluation. These are suggestions and not all will apply to any given proposal. Each reviewer will be asked to address only those that are relevant to the proposal and for which he/she is qualified to make judgements.

What is the intellectual merit of the proposed activity?

How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of the prior work.) To what extent does the proposed activity suggest and explore creative and original concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

What are the broader impacts of the proposed activity?

How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?

Principal Investigators should address the following elements in their proposal to provide reviewers with the information necessary to respond fully to both of the above-described NSF merit review criteria. NSF staff will give these elements careful consideration in making funding decisions.

Integration of Research and Education

One of the principal strategies in support of NSF's goals is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions provide abundant opportunities where individuals may concurrently assume responsibilities as researchers, educators, and students and where all can engage in joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives.

Integrating Diversity into NSF Programs, Projects, and Activities

Broadening opportunities and enabling the participation of all citizens -- women and men, underrepresented minorities, and persons with disabilities -- is essential to the health and vitality of science and engineering. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports.

A summary rating and accompanying narrative will be completed and signed by each reviewer. In all cases, reviews are treated as confidential documents. Verbatim copies of reviews, excluding the names of the reviewers, are sent to the Principal Investigator/Project Director by the Program Director. In addition, the proposer will receive an explanation of the decision to award or decline funding.

B. Review Protocol and Associated Customer Service Standard

All proposals are carefully reviewed by at least three other persons outside NSF who are experts in the particular field represented by the proposal. Proposals submitted in response to this announcement/solicitation will be reviewed by Mail and/or panel review.

Reviewers will be asked to formulate a recommendation to either support or decline each proposal. The Program Officer assigned to manage the proposal's review will consider the advice of reviewers and will formulate a recommendation.

In most cases, proposers will be contacted by the Program Officer after his or her recommendation to award or decline funding has been approved by the Division Director. This informal notification is not a guarantee of an eventual award.

NSF will be able to tell applicants whether their proposals have been declined or recommended for funding within six months for 95 percent of proposals. The time interval begins on the proposal deadline or target date or from the date of receipt, if deadlines or target dates are not used by the program. The interval ends when the Division Director accepts the Program Officer's recommendation.

In all cases, after programmatic approval has been obtained, the proposals recommended for funding will be forwarded to the Division of Grants and Agreements for review of business, financial, and policy implications and the processing and issuance of a grant or other agreement. Proposers are cautioned that only a Grants and Agreements Officer may make commitments, obligations or awards on behalf of NSF or authorize the expenditure of funds. No commitment on the part of NSF should be inferred from technical or budgetary discussions with a NSF Program Officer. A Principal Investigator or organization that makes financial or personnel commitments in the absence of a grant or cooperative agreement signed by the NSF Grants and

Agreements Officer does so at its own risk.

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

Notification of the award is made to *the submitting organization* by a Grants Officer in the Division of Grants and Agreements. Organizations whose proposals are declined will be advised as promptly as possible by the cognizant NSF Program Division administering the program. Verbatim copies of reviews, not including the identity of the reviewer, will be provided automatically to the Principal Investigator. (See section VI.A. for additional information on the review process.)

B. Award Conditions

An NSF award consists of: (1) the award letter, which includes any special provisions applicable to the award and any numbered amendments thereto; (2) the budget, which indicates the amounts, by categories of expense, on which NSF has based its support (or otherwise communicates any specific approvals or disapprovals of proposed expenditures); (3) the proposal referenced in the award letter; (4) the applicable award conditions, such as Grant General Conditions (NSF-GC-1)* or Federal Demonstration Partnership (FDP) Terms and Conditions * and (5) any announcement or other NSF issuance that may be incorporated by reference in the award letter. Cooperative agreement awards also are administered in accordance with NSF Cooperative Agreement Terms and Conditions (CA-1). Electronic mail notification is the preferred way to transmit NSF awards to organizations that have electronic mail capabilities and have requested such notification from the Division of Grants and Agreements.

*These documents may be accessed electronically on NSF's Web site at http://www.nsf.gov/home/grants/grants_gac.htm. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (301) 947-2722 or by e-mail from pubs@nsf.gov.

More comprehensive information on NSF Award Conditions is contained in the NSF *Grant Policy Manual* (GPM) Chapter II, available electronically on the NSF Web site at <http://www.nsf.gov/cgi-bin/getpub?gpm>. The GPM is also for sale through the Superintendent of Documents, Government Printing Office (GPO), Washington, DC 20402. The telephone number at GPO for subscription information is (202) 512-1800. The GPM may be ordered through the GPO Web site at <http://www.gpo.gov>.

C. Reporting Requirements

For all multi-year grants (including both standard and continuing grants), the PI must submit an annual project report to the cognizant Program Officer at least 90 days before the end of the current budget period.

Within 90 days after the expiration of an award, the PI also is required to submit a final project report. Approximately 30 days before expiration, NSF will send a notice to remind the PI of the requirement to file the final project report. Failure to provide final technical reports delays NSF

review and processing of pending proposals for that PI. PIs should examine the formats of the required reports in advance to assure availability of required data.

NSF has implemented an electronic project reporting system, available through FastLane. This system permits electronic submission and updating of project reports, including information on project participants (individual and organizational), activities and findings, publications, and other specific products and contributions. PIs will not be required to re-enter information previously provided, either with a proposal or in earlier updates using the electronic system.

VIII. CONTACTS FOR ADDITIONAL INFORMATION

General inquiries regarding Quantum and Biologically Inspired Computing should be made to:

- Mita Desai, Program Director, CISE/EIA, Rm 1160, telephone: (703)292-8980, e-mail: mdesai@nsf.gov.

For questions related to the use of FastLane, contact:

- Helen A. Walston, Senior Program Assistant, Division of Experimental and Integrative Activities (CISE/EIA), telephone: (703)292-8980.

IX. OTHER PROGRAMS OF INTEREST

The NSF *Guide to Programs* is a compilation of funding for research and education in science, mathematics, and engineering. The NSF *Guide to Programs* is available electronically at <http://www.nsf.gov/cgi-bin/getpub?gp>. General descriptions of NSF programs, research areas, and eligibility information for proposal submission are provided in each chapter.

Many NSF programs offer announcements or solicitations concerning specific proposal requirements. To obtain additional information about these requirements, contact the appropriate NSF program offices. Any changes in NSF's fiscal year programs occurring after press time for the *Guide to Programs* will be announced in the NSF [E-Bulletin](#), which is updated daily on the NSF web site at <http://www.nsf.gov/home/ebulletin>, and in individual program announcements/solicitations. Subscribers can also sign up for NSF's [Custom News Service](#) (<http://www.nsf.gov/home/cns/start.htm>) to be notified of new funding opportunities that become available.

Cross Directorate Programs:

Information Technology Research, <http://www.itr.nsf.gov/> Nanoscale Science and Engineering, <http://www.nsf.gov/home/crssprgm/nano/start.htm>

Programs within individual Directorates:

Theory of Computing (CCR/CISE)

Computer Systems Architecture (CCR/CISE)

Biological Information Technology and Systems(EIA/CISE)

Condensed Matter Physics(DMR/MPS)

Materials Theory(DMR/MPS)

Atomic Molecular Optical and Plasma Physics (PHY/MPS)

Theoretical and Computational Chemistry (CHE/MPS)

Control, Networks and Computational Intelligence(ECS/ENG)

Molecular Biophysics (MCB/BIO)

Biological Databases and Infrastructure (DBI/BIO)

Electronic and Photonic Device Technology (ECS/ENG)

ABOUT THE NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) funds research and education in most fields of science and engineering. Awardees are wholly responsible for conducting their project activities and preparing the results for publication. Thus, the Foundation does not assume responsibility for such findings or their interpretation.

NSF welcomes proposals from all qualified scientists, engineers and educators. The Foundation strongly encourages women, minorities and persons with disabilities to compete fully in its programs. In accordance with Federal statutes, regulations and NSF policies, no person on grounds of race, color, age, sex, national origin or disability shall be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving financial assistance from NSF (unless otherwise specified in the eligibility requirements for a particular program).

Facilitation Awards for Scientists and Engineers with Disabilities (FASSED) provide funding for special assistance or equipment to enable persons with disabilities (investigators and other staff, including student research assistants) to work on NSF-supported projects. See the program announcement/solicitation for further information.

The National Science Foundation has Telephonic Device for the Deaf (TDD) and Federal Information Relay Service (FIRS) capabilities that enable individuals with hearing impairments to communicate with the Foundation about NSF programs, employment or general information. TDD may be accessed at (703) 292-5090, FIRS at 1-800-877-8339.

The National Science Foundation is committed to making all of the information we publish easy to understand. If you have a suggestion about how to improve the clarity of this document or other NSF-published materials, please contact us at plainlanguage@nsf.gov.

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

The information requested on proposal forms and project reports is solicited under the authority of the National Science Foundation Act of 1950, as amended. The information on proposal forms will be used in connection with the selection of qualified proposals; project reports submitted by awardees will be used for program evaluation and reporting within the Executive Branch and to Congress. The information requested may be disclosed to qualified reviewers and staff assistants as part of the proposal review process; to applicant institutions/grantees to provide or obtain data regarding the proposal review process, award decisions, or the administration of awards; to government contractors, experts, volunteers and researchers and educators as necessary to complete assigned work; to other government agencies needing information as part of the review process or in order to coordinate programs; and to another Federal agency, court or party in a court or Federal administrative proceeding if the government is a party. Information about Principal Investigators may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records," 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records," 63 Federal Register

268 (January 5, 1998). Submission of the information is voluntary. Failure to provide full and complete information, however, may reduce the possibility of receiving an award.

Pursuant to 5 CFR 1320.5(b), an agency may not conduct or sponsor, and a person is not required to respond to an information collection unless it displays a valid OMB control number. The OMB control number for this collection is 3145-0058. Public reporting burden for this collection of information is estimated to average 120 hours per response, including the time for reviewing instructions. Send comments regarding this burden estimate and any other aspect of this collection of information, including suggestions for reducing this burden, to: Suzanne Plimpton, Reports Clearance Officer, Information Dissemination Branch, Division of Administrative Services, National Science Foundation, Arlington, VA 22230, or to Office of Information and Regulatory Affairs of OMB, Attention: Desk Officer for National Science Foundation (3145-0058), 725 17th Street, N.W. Room 10235, Washington, D.C. 20503.

OMB control number: 3145-0058.