

**Report of the SIGACT Committee on Funding for Theoretical Computer Science
Presented at the FOCS Business Meeting, Oct. 24, 2005
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Introduction

In the spring of 2005 there was an upsurge of alarm in the Theoretical Computer Science community about the growing difficulty of acquiring adequate research funding. Sanjeev Arora, Avi Wigderson and Boaz Barak took the lead in addressing this problem. They prepared a white paper describing the contributions of theoretical computer science and explaining the need for improved funding, and persuaded the SIGACT leadership to form a committee to look into the problem. The members of the committee are Sanjeev Arora, Joan Feigenbaum, Dick Karp (Chair), Dick Lipton, Michael Mitzenmacher, Christos Papadimitriou, Bob Sloan, Madhu Sudan, Eva Tardos, Avi Wigderson, Hal Gabow (*ex officio*) and Richard Ladner (*ex officio*).

The foremost goal of this committee is to improve the stature and support of TCS within NSF. The inferior position of TCS within the organizational structure of the CISE Directorate of NSF, in comparison with the other main branches of computer science, is the biggest impediment to achieving a level of funding that will enable our community to develop the foundations of computer science, train the next generation of outstanding researchers, and respond to new research challenges.

Our additional goals are to develop funding opportunities for theoreticians through other federal agencies and to work with the Computing Research Association (CRA) and Congress to increase federal support for computer science.

Status of Theory Funding

To understand the status of TCS funding from NSF we made a detailed study of the NSF funding received during the period 2000-2004 by a group of 90 funded investigators who are clearly identified with TCS. The program responsible for Foundations of Theoretical Computer Science provided 23% of their funding, and 55% came for the ITR program. The average number of grants per investigator during the period was 2.4, and the median grant size (per investigator per year) was \$70,000.

The implications of this data are troubling. The ITR program is terminating and no program of comparable scale is slated to replace it. Even during the ITR era the small size of typical grants has forced investigators to submit multiple proposals in order to support their students and research activities. This has created a burden not only on them but on the capacity of NSF to review proposals. Moreover, the future commitments of the TCS Foundations program (funded at \$6M per year in fiscal 2005) have obliged it to declare a moratorium on receiving new proposals. **TCS researchers have contributed vastly to the development of computer science, and to the establishment of many new areas of research: recent examples include bioinformatics, quantum computing, Internet content distribution, web research, parallel algorithms and architectures. As computer science enters a new era of interdisciplinary opportunities and challenges, TCS will play an even more**

important role. If TCS research funding undergoes the hard times that we fear, the U.S. leadership position in this critical area of technology will be eroded.

Facts About NSF

If approved by Congress CISE will have a budget of \$495M for the 2006 fiscal year. Expectations are that the budgets of NSF and CISE will be flat for the next few years. CISE is divided into three directorates: Information and Intelligent Systems (responsible for database research, information retrieval, machine learning, AI etc.), Computer and Network Systems, and Computing and Communications Foundations (CCF).

The position of TCS within the CISE organization is not commensurate with its importance. In contrast to the prominent positioning of databases, AI and networking, TCS is but one component of a theoretical foundations cluster within CCF funded at about \$40M per year. In addition to TCS this cluster is responsible for scientific computing, communication theory and signal processing, and image analysis. In 2005 the portion of the budget specifically allocated to TCS was \$6M, and a modest increase is expected for 2006. Bill Steiger from Rutgers will be joining the cluster as a Program Director. The cluster is also searching for a Program Director in the area of logic and program verification. With help from Moshe Vardi we have identified some excellent candidates for this position and put them in touch with Michael Foster, Director of CCF. To foster innovation about 1/3 of the cluster's funding is reserved for new ventures that can come from any of the areas covered. By providing suggestions to the Program Directors we hope to acquire some of this "floating" money for TCS.

NSF has launched a major new program called GENI (Global Environment for Networking Investigations). GENI is expected to spend about \$300M on an experimental testbed for new architectures. GENI will also include a budget of about \$10M per year for associated research studies in six designated areas, one of which is "Developing new network architecture theories: investigating network complexity, scalability and economic incentives."

Cooperation with CISE

We are working to establish a spirit of open communication and cooperation with the leaders of CISE. This includes the following goals:

- (1) Increase the understanding and appreciation of TCS among CISE staff, and give them ammunition for promoting TCS.
- (2) Identify TCS people to do rotations at CISE, at all levels of the organization.
- (3) Serve as a sounding board for Directors and Program Officers.
- (4) Increase the representation of TCS on the CISE Advisory Board, grant review panels and internal evaluation committees.

Coupled with these efforts are our funding goals, which include:

- (1) Make a well-documented case that TCS is underfunded.
- (2) Move TCS up in the CISE hierarchy.
- (3) Streamline the funding process, for both proposers and reviewers.
- (4) Develop cross-cutting NSF initiatives relevant to TCS.

Visit to NSF

On August 31 Richard Lipton and I visited NSF on behalf of the committee. We had extensive cordial discussions with CISE Director Peter Freeman, CISE Division Directors and the leaders of the GENI initiative, among others. I gave a public talk, prepared jointly with the committee and with technical assistance from Boaz Barak. The talk stressed two themes: the universal threads that lie at the core of TCS, and promising new directions for TCS. To illustrate the universal threads the talk presented a number of examples of natural and fundamental questions, easily grasped by nonspecialists, that drive the field: These included the P vs. NP question and its implications for combinatorial search and cryptography, efficient algorithms for familiar problems such as multiplying integers, novel proof concepts such as interactive, zero-knowledge and probabilistically checkable proofs, the power of randomization and quantum computing, the challenge of incentivizing self-interested agents to cooperate over the Internet, and fundamental limits on asynchronous computation in the presence of faults and on the ability of computers to infer patterns from examples.

The second part of the talk suggested a new NSF initiative in **Theory of Networked Computation** that would cut across all parts of the CISE agenda and would include topics closely related to the GENI initiative. The emergence of large networks such as the Web is a profound shift in the focus of computer science. Networks are built, operated and used by parties with diverse interests and varying degrees of cooperation and competition. The initiative would address the challenges of building and managing large systems consisting of autonomous parties, while ensuring the rights of individuals and full and fair exploitation of shared resources.

The TCS community has responded very vigorously to new algorithmic challenges linked to the spread of the Web. We have made major advances in search and information retrieval, network protocols, error-correcting codes for storage and communication, peer-to-peer networks, E-commerce, Internet-based auctions, mechanism design and massive distributed data sets. Our colleagues and students are playing an important role in companies such as Google, Yahoo and Akamai. To continue this thrust we proposed an agenda for Theory of Networked Computation encompassing: security and privacy; incentives, pricing and sharing; massive data sets; reliable storage and communication; and complexity theory of networked computation.

The Committee's Current Agenda

At the suggestion of Peter Freeman we have requested a grant to support planning for a possible NSF initiative in Theory of Networked Computation. The grant would underwrite two small workshops to be held next spring, bringing together TCS researchers and networking researchers to sharpen the focus of this initiative and hopefully lead to a new cross-cutting NSF program.

We are in the preliminary stages of formulating a second initiative, complementary to the Theory of Networked Computation, focusing on the process by which the new ideas constantly being gestated within TCS can influence a variety of application areas and provide a computational perspective on different fields of science. Vijay Vazirani is helping us in this effort.

At the request of the CISE leadership we are preparing a report on the appropriate target funding level for TCS within NSF. Our proposal will present data on the funding of TCS compared to other areas of computer science, and will present our vision of the benefits that enhanced funding of TCS research and training can provide to our field and the nation. One preliminary finding is that 15% of the faculty in the top 24 computer science departments are identified with TCS, but TCS research receives only about 6% of the CISE funding. We will try to understand whether this apparent discrepancy has a rational basis, or whether it is perhaps an artifact of the placement of TCS within the hierarchical structure of CISE.

At Peter Freeman's request we will prepare a pamphlet, to be published by the Computing Research Association, setting forth some of the universal themes underlying TCS and the fundamental challenges that our field addresses, at a level accessible to all intelligent readers. Our premise will be that the driving problems at the root of our discipline are as exciting and worthy of support as the better-known problems at the roots of fields such as cosmology and physics. In preparation for this publication the committee, helped by colleagues in the TCS community, has prepared preliminary "white papers" on universal themes in TCS, the magic of TCS, the theory of networked computation, reliable digital communication, computational biology, quantum computing, statistical physics (by Alistair Sinclair), nanotechnology (by John Savage), and logic and program verification (by Moshe Vardi). Members of the TCS community are invited to submit additional white papers.

A Challenge to the TCS Community

Ensuring healthy research support for the TCS community is a continuing challenge that has no time limit and should not be delegated to few individuals. We ask every TCS researcher to look for ways to serve our community, whether by writing expository articles explaining TCS to the public, representing our community at NSF, participating in a community dialogue about funding mechanisms and new research programs, or volunteering to join our committee as its membership changes in the coming years.