Computer Systems Research (CSR)

Program Solicitation
NSF 07-504

Replaces Document(s):
NSF 05-629

National Science Foundation

Directorate for Computer & Information Science & Engineering
Division of Computer and Network Systems

Full Proposal Deadline(s) (due by 5 p.m. proposer's local time):

January 17, 2007

Second Friday in November, Annually Thereafter

REVISION NOTES

In furtherance of the President's Management Agenda, NSF has identified programs that will offer proposers the option to utilize Grants.gov to prepare and submit proposals, or will require that proposers utilize Grants.gov to prepare and submit proposals. Grants.gov provides a single Government-wide portal for finding and applying for Federal grants online.

In response to this program solicitation, proposers may opt to submit proposals via Grants.gov or via the NSF FastLane system. In determining which method to utilize in the electronic preparation and submission of the proposal, please note the following:

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via the NSF FastLane system. Chapter II, Section D.3 of the Grant Proposal Guide provides additional information on collaborative proposals.

The following revisions have been made to last year's solicitation:

- Three thematic areas are announced, complementing the core research areas that were previously referred to as “topical areas”.
- Updates and clarifications have been made to the Introduction and Program Description sections of this solicitation. PIs are advised to read these sections carefully and to contact a CSR Program Officer with any questions.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Computer Systems Research (CSR)

Synopsis of Program:

Computer systems are ubiquitous, and society is increasingly dependent on them. They range from microprocessors embedded in automobiles and appliances, to worldwide grids of advanced processors, storage, graphics devices, and instruments interconnected by high-speed networks. Computer systems include large amounts of systems software. Systems software has two main roles: to provide abstractions and services that facilitate the implementation and execution of application programs; and, to orchestrate effective use of the underlying hardware resources through these abstractions and services. Computer systems are being applied to increasingly demanding applications. The environments in which they function and the resource configurations to be orchestrated are becoming more diverse, distributed and dynamic. While the time scales for control decisions are shrinking, the scale and complexity of the systems are increasing. The assumptions underlying current system software no longer hold in many cases. Moreover, current computer systems often fail, become compromised or perform poorly because of failures of system software. Responding to these challenges requires new directions in computer systems research.

The Computer Systems Research (CSR) program supports innovative research and education projects that have the potential to:

- lead to significant improvements in computer systems by increasing our fundamental understanding of them;
- address challenges raised by new technologies or system requirements;
- lead to systems software that is quantifiably more reliable, easier to use, and/or more efficient; and
- produce innovative curricula or educational materials that better prepare the next generation of computing professionals.

The CSR program also supports projects that expand the capabilities of computer systems by exploiting the potential of new technologies or by developing innovative new ways to use existing technologies. CSR-funded projects will strive to make significant progress on challenging high-impact problems, as opposed to incremental progress on familiar problems. To be successful, CSR proposals must have credible plans for demonstrating the utility and potential impact of the proposed work.

The CSR program is partitioned into two parts:

- CORE areas - to support traditional CSR research and education topics. CSR core areas are: Embedded and Hybrid Systems (EHS); Parallel and Distributed Operating Systems (PDOS); Advanced Execution Systems (AES); and Systems Modeling and Analysis (SMA). Awards in the core areas may take one of two forms:
  - Single Investigator and Small Group awards. These awards will include one or two PIs, with budgets of up to $800,000 total, and award durations of two or three years. The estimated average award size is $450,000.
  - Team awards. These awards will include three or more PIs, with budgets of up to $1,500,000 total, and award durations of three or four years. The estimated average award size is $900,000.
- THEMATIC areas - to stimulate research and education in topics that are considered timely and of emerging importance. Specific thematic areas may change from year to year. In FY 2007, the thematic areas are: Cross-Systems Integration (CSI); Virtualization for Configuration Management (VCM); and, Cyber Physical Systems (CPS). Awards in the thematic areas will be smaller by design, with funding levels ranging from $200,000 to $400,000 total, and with award durations of one or two years.

On occasion, the CSR program will accept proposals for workshops and Small Grants for Exploratory Research (SGERs). These proposals may be submitted on or before the deadline for this solicitation under the conditions described herein, or they may be submitted at any other time in accordance with GPG guidelines. However, prior to submission of any workshop or SGER proposal, a PI must discuss their interests with a CSR Program Officer before submitting the proposal. Additional information about SGER proposals can be found in Section II.D.1. of the NSF Grant Proposal Guide (GPG).

Cognizant Program Officer(s):

- Brett Fleisch, Program Director, 1175 N, telephone: (703) 292-4541, fax: (703) 292-9010, email: bfleisch@nsf.gov

- Frederica Darema, Senior Science and Technology Advisor, 1175 N, telephone: (703) 292-8950, fax: (703) 292-9010, email: fdarema@nsf.gov

- D. Helen Gill, Program Director, 1175 N, telephone: (703) 292-8950, fax: (703) 292-9010, email: hgill@nsf.gov

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

- 47.070 --- Computer and Information Science and Engineering

Award Information

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 40 to 65 awards total. 20 to 30 Individual and Small group awards and 3 to 6 Team awards in the CSR CORE areas, and 20 to 30 awards in the CSR THEMATIC areas.

Anticipated Funding Amount: $28,000,000 in FY 2007. Awards will be made subject to the availability of funds.

Eligibility Information

Organization Limit:

None Specified

PI Limit:

None Specified

Limit on Number of Proposals per Organization:

None Specified

Limit on Number of Proposals per PI: 2

An individual may appear as PI, co-PI or Senior Personnel on no more than two proposals per annual CSR competition.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Not Applicable

- **Full Proposals:**

  - Full Proposals submitted via FastLane: Grant Proposal Guide (GPG) Guidelines apply. The complete text of the GPG is available electronically on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg.

  - Full Proposals submitted via Grants.gov: NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov Guidelines apply (Note: The NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: http://www.nsf.gov/bfa/dias/policy/docs/grantsgovguide.pdf/)

B. Budgetary Information

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

C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. proposer's local time):

  January 17, 2007

  Second Friday in November, Annually Thereafter

Proposal Review Information Criteria

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

TABLE OF CONTENTS

I. INTRODUCTION

Computing platforms and applications are increasingly complex and dynamic. They also cover a wide range of technologies and capabilities, such as: globally distributed, heterogeneous platforms; high-end computing systems; LAN-based enterprise systems; workstation clusters; shared-memory multiprocessors; mobile and special-purpose embedded systems; real-time systems; process and supervisory controllers; and assemblies of embedded sensor systems and physical control actuation devices.

The Computer Systems Research (CSR) program supports innovative research and education projects that will lead to better computer systems by increasing our fundamental understanding of such systems and by producing better systems software. The program aims to support projects that have the potential to: lead to significant increases in fundamental understanding of systems software; address challenges raised by new technologies and/or system requirements; lead to systems software that is quantifiably more reliable, easier to use and/or more efficient; and, produce innovative curricula or educational materials focused on future generations of systems software.

CSR supports the development of innovative curricular materials that have the potential to significantly improve computer systems related higher education. Education-focused activities may be submitted as stand-alone projects, or may be included as components of broader research and education projects. Stand-alone curriculum development projects are expected to include strong justification of the need for the new materials and must include both plans for disseminating them to the community, and for evaluating their effectiveness. Proposals which solely focus on education should be discussed with CSR Program Officers before they are submitted.

CSR proposals should describe how the project will demonstrate potential impact (e.g., by validating theories on real systems, by demonstrating the utility of new systems software and making it available to the community, and/or by disseminating and evaluating new educational materials or curricula).

II. PROGRAM DESCRIPTION

The CSR program consists of two parts: CORE areas and THEMATIC areas as described below.

CORE Areas

Core areas support research and education projects focused on traditional CSR topics: Embedded and Hybrid Systems, Parallel and Distributed Operating Systems (PDOS), Advanced Execution Systems (AES) and Systems Modeling and Analysis (SMA). Each is described below.

Embedded and Hybrid Systems (EHS)

Information technology for embedded and hybrid systems is a key accelerator of progress and innovation in modern engineered systems. Embedded and hybrid systems control devices and physical or engineered systems that range from hearing aids and automobiles, to electrical power grids and global aviation infrastructure. The nation's critical infrastructures depend on embedded sensing and hybrid control systems. However, current systems are built on top of decades-old technology, often as closed, centralized systems. Future supervisory and real-time process control systems must be open and interoperable with other systems in a widely distributed environment.

EHS supports research and education in scientific foundations and systems technology that will revolutionize the design and development of embedded and hybrid systems. EHS emphasizes temporal and dynamic (discrete and continuous) aspects of computational control for this class of systems. The goals of this area are to create and unify the foundations for interacting physical and computational systems and to supply technologies needed for building reliable embedded systems. Achieving these goals requires a rethinking of the underpinnings, architectures, and system implementation philosophies for these kinds of systems. A pervasive theme for the EHS area is the creation of high-confidence systems that integrate functionality with mechanisms that provide real-time, survivability, reliability, and security guarantees. Key drivers for this theme are the coordination demands that are required by future generations of complex, networked embedded systems. The area draws upon control theory, modeling, software generation, real-time and resource-aware scheduling, and formal methods.

Specific topics of interest include:

- Embedded systems software and composition technology: highly innovative concepts and methods for middleware, virtual machines, and system services; new concepts and methods for high confidence, distributed, real-time operating systems; component technology for functional and non-functional aspects of systems; and programming methods for integration of embedded system services.
- Foundations and technology for distributed software control: hybrid discrete and continuous models for predicting behavior of systems; new concepts, and services to support and secure future generation supervisory control and data acquisition (SCADA) systems and process control systems (PCS); and scalable support for embedded sensors and sensor nets.
- Methods for semantically-grounded modeling and design of embedded software and systems: foundations, design, implementation, synthesis, analysis, and certification methods and tools; and innovative approaches for failure modes, self-test, and recovery and reconstitution.
- Resource management and optimization: methods and tools for allocating, scheduling, and managing real-time, power-aware distributed embedded systems; and static and real-time dynamic scheduling technology that addresses and integrates multiple concern such as real-time guarantees, power, clock frequency, thermal gain, emission and interference in the electromagnetic spectrum, network bandwidth, task dependence, and criticality level.

Parallel and Distributed Operating Systems (PDOS)

Most computer systems are general-purpose, meaning that they use commodity hardware and the systems software to support a variety of applications. This practice contrasts with special purpose systems (e.g., many real-time systems), which are closely tied to a single application and often use customized hardware. General-purpose computer systems include uniprocessors, shared-memory multiprocessors, mobile devices and applications, local area distributed systems, clusters, wide area distributed systems, and computational grids.

PDOS supports research and education projects that advance the state of the art in general purpose operating systems and distributed systems as described above. The goals are to improve the capabilities, reliability, and efficiency of existing systems, to create new ways to utilize current technologies, and to harness the potential of emerging technologies. Projects are expected to increase our fundamental understanding of how to design and build better operating systems and distributed systems and/or to create new types of systems and systems services. Successful proposals should demonstrate their utility through empirical prototypes that are evaluated and disseminated to the community.

Specific topics of interest include the following:

- Resource management: scheduling, virtual memory management and protection; management of multiple levels of memory hierarchy and file systems; process and data migration; scalable and robust methods for communication and synchronization; virtualization of resources and efficient resource utilization; and resource management across heterogeneous platforms with distinct administrative boundaries.
- System services: mechanisms that enable dynamic coalitions, such as peer-to-peer or ad-hoc groups; membership, naming, and authorization services; local and remote resource discovery and resource requests services; system monitoring for performance tuning or to provide resilience to faults; support for debugging large, widely dispersed distributed systems; checkpoint and recovery services; configuration management; and customizable and adaptable systems services.
- System architecture: new ways to organize systems, such as peer-to-peer; system software architectures that scale to handle thousands of components; software architectures addressing changing trends, such as sizes or speeds of processors, memory, address spaces, storage and backing store; multi-threaded kernel design and kernel-level management functions for end-to-end provisioning of services; and dynamic, customizable kernels.
- System properties: fault-tolerance and reliability; efficiency; security; scalability; and, ability to cope with unexpected events; improving manageability, configurability and accountability while reducing the associated costs and overheads.

Advanced Execution Systems (AES)

Advanced applications execute on large, heterogeneous high-end computing and grid platforms, require multiple resources, ranging from fast processors to large and distributed data stores, and consume large amounts of communication network bandwidth. These applications may have dynamically changing resource requirements. In addition, the underlying resources available to an application may change dynamically due to competing demands from other applications. Consequently, an advanced execution environment must support adaptive mapping of applications to underlying resources during execution.

AES supports research and education projects that create systems software to facilitate the development and dynamic runtime support environments for complex applications. The systems sought here interface with operating systems services, such as those developed in the PDOS core area, and they incorporate methods and tools developed in the SMA core area. Research interests include: programming models and environments, compilers, runtime, resource management support, and application debugging, fault-tolerance and recovery methods. To meet these and other execution requirements, new

directions are sought in the areas discussed below.

- Advanced Programming Environments and Compilers: A runtime compiling system (RCS) extends the standard static notion of a compiler by embedding a portion of the compiler in the runtime system and endowing the RCS system with resource awareness and adaptive mapping capabilities. Research scope includes:

    - Advances in distributed programming models and environments, including application level assists and knowledge-based systems to facilitate the RCS to optimally map the application across distributed, heterogeneous, and complex computing platforms. Such models can be appropriate extensions of existing programming models.

    - New compiler techniques creating RCS capabilities, such as determining functional and data dependencies across multiple levels of memory hierarchies and across platforms, and mechanisms for matching an application's resource needs to underlying resources when one or both are changing as the application executes.

    - Advances in tools and techniques in areas such as debugging in dynamic runtime environment, application-level check-pointing and capability to remap parts of the application to other platforms.

    - New methods of instrumentation and measurement, which will be accessible to the RCS for application diagnosis and mapping.

- Application Composition Systems: An application composition system (ACS) allows an application to be constructed to fit the available resources and to adapt to changes in the underlying execution environment. It also supports application-level monitoring, debugging, and recovery. An ACS interacts with and supports an RCS to compose applications dynamically. Creating an ACS requires a number of technological advances, including:

    - Development of methods for problem specification and content information extraction for automatically selecting such application components;

    - Designing methods for automatically selecting application components suitable to the application problem specifications and the underlying platforms;
    - Interfacing with the underlying computing platform models to determine dynamically at runtime suitable application components;
    - Creating knowledge bases for application components as well as technology for RCS-enabled and knowledge-based application composition; and,
    - Development of appropriate application component libraries and interfaces so the run-time portion of the RCS can link to such libraries.

Systems Modeling and Analysis (SMA)

The SMA core area supports the development of methods and tools that enable modeling, measuring, analyzing, evaluating and predicting the performance, correctness, efficiency, and dependability of complex computing and communications systems. The capabilities sought should enhance the state-of-the-art for architecting, designing and operating such systems. Capabilities enabling optimizations meeting multiple objectives and constraints are also desired. Ideally, these methods and tools will be general and powerful enough to be applicable to the range of platforms addressed in this solicitation, from embedded systems, to parallel and distributed systems, to high-end processing and computational grids.

Topics of interest include:

- Methods and tools that support analysis of all levels of a system (hardware, systems software, and application) in terms of individual components as well as of entire systems.
- Methods and tools, such as performance frameworks, that employ models and measurements (in a plug-and-play fashion) of different levels of detail of each component and layer, as needed for the specific analysis at hand.
- Methods that provide hierarchical or multilevel analysis of such systems and/or enable assessment of the effects of individual hardware and software layers and components of these systems. These methods should be incorporable in performance frameworks to enable assessment of the impact of different system components on the performance of the entire system.
- Methods to enable modeling of how the behavior of a system scales as aspects of the application, systems software, or hardware change; for example, when one shifts from a small prototype to a production environment or from one machine or to another with different architectural features.
- Validation and Demonstration of the Technologies: Integral aspects of the projects sought are to provide validation of

key technologies described above and integration of the individual technologies into an application design and support system.

THEMATIC Areas

The thematic areas are identified to stimulate research and education in areas that are considered timely and of emerging importance. These areas have been identified through meetings and discussions among members of the CISE community, NSF program directors, and CISE management. Funded projects in these thematic areas are expected to yield research and education concepts and prototypes that may become the subject of further development and evaluation. In the FY 2007 CSR competition, there are three thematic areas: Cross-Systems Integration (CSI); Virtualization for Configuration Management (VCM); and Cyber Physical Systems (CPS). Each is described below.

Cross-Systems Integration (CSI)

The CSI area calls for ambitious projects whose research goals are to seamlessly support dynamically integrated computational and real-time data acquisition environments, with an emphasis on the integrative aspects of systems software across the spectrum of such environments. Measurement processes involve instruments or sensors and sensor networks, and data acquisition, storage and access. Traditionally, computation and data acquisition aspects of an application have been considered separate processes. In the emerging environments considered here, they are dynamically correlated, with data dynamically streamed into an executing application and in reverse the executing application controlling and steering the measurement process.

These emerging environments go beyond traditional control systems, which typically deal with special purpose applications and customized data acquisition, and where the interaction between model and measurement entails an analytic function representing the application model, with an ensuing simple relation between model and measurement. In distinction, in the dynamic systems addressed here, a simulation represents the application model. The application platform may include high-end and/or other distributed computing platforms as well as real-time data acquisition systems (such as instruments and sensors), expanding the traditional concept of computational grids to encompass data acquisition platforms.

These environments pose the need for seamless and dynamic integration, and for satisfying the requirements of the general computational environments and the constraints of data acquisition systems. Research challenges include novel architectures that drill through all layers of the systems stack, while at the same time, spanning the two traditionally distinct domains of computational systems and real-time systems. Areas of interest include:

- Programming environments: Application programming environments and development tools which unify and integrate support for multiple programming models and which satisfy the requirements of a spectrum of underlying platforms are needed. The capabilities required include application embedded sensing and actuating mechanisms for specifying, discovering, negotiating, and adapting to policies and constraints, support for dynamic workflow and support for dynamic application composition and invocation of application components driven by dynamic data inputs. Capabilities for end-to-end optimization across software layers and the heterogeneous spectrum of underlying hardware systems including computing, communications, data systems as well as instruments and distributed sensor systems are needed.
- Integrated runtime management: The runtime management of environments considered here requires end-to-end integrated methods and tools for resource management and optimization that satisfy the differing requirements of mission critical and traditional computational systems. Runtime management needs to support the dynamic resource requirements, at the application level and at the data acquisition level, and dynamic allocation and mapping across such heterogeneous underlying resources. This includes compilers, debuggers, and other system software that span the diverse spectrum of underlying systems. Capabilities sought include: support for adaptive real-time response across computational and instrumentation systems; ability of the runtime system software to interface with multiple operating systems and other services that reside on the diverse spectrum of underlying platforms.
- Integrated system services: End-to-end across-system services are needed in order to seamlessly and simultaneously satisfy requirements of the real-time and the computational components of an application. Such integrated services span: system-level end-to-end performance optimization, performance guarantees over a wide range of system capabilities including real-time, just in-time resource allocation, system-wide time–synchronization, event/data logging, just in-time data transport, power-awareness, efficiency, reliability, fault-tolerance, recovery and security. Furthermore, it is also critical to dynamically manage and integrate data, resulting from different sources (computation, data acquisition, archival storage), and produced from mutiple data models and across multiple time-scales. Systems software methods and tools that dynamically integrate computation and measurement to guide architecture and enable adaptive control of sensor networks are also required.

Proposals may span more than one of the categories in the CSI thematic area.

Virtualization for Configuration Management (VCM)

The VCM area calls for ambitious research and education proposals that seek to advance virtualization technology and its application to system configuration management.

A major research challenge lies in the management, maintenance, and evolution of computer systems. On one hand, rapid advances in system technologies (at processor, operating system, and programming language levels) push for frequent re-configuration, upgrade, and even replacement of the computer and device components. On the other hand, the potentially large quantity, wide deployment, or hostile operating environment of computer systems makes it difficult to perform such tasks efficiently and effectively. Thus, configuration and administrative management has been an increasingly costly factor in today's computer systems. If we continue down the current path, management costs will soar to unacceptable levels.

To address this challenge, the VCM area seeks proposals that leverage and/or spur technological innovation in virtualization-based system management, maintenance, and evolution. Virtualization creates instances of a computer system that can be useful to study computer system configurations and management. Like physical machines, virtual machines provide CPU cycles, storage and bandwidth, but they do so by mapping virtual resources to physical resources. Thus, a given physical system can support multiple virtualized architectures enabling experiments that would otherwise be difficult with the physical platform and its associated software. The focus in the VCM area is to use virtualization as a methodology to enable support for developing better configuration management. Areas of interest are:

- Monitoring software and tools to monitor the embedded systems, networks, clusters, or distributed systems. This technology is used to inspect and determine the system's state from various levels of abstraction, monitoring various hardware configurations for reliability, performance, and to sustain continuously-improved operation. One way to monitor a system is to virtualize the system and to extrapolate expected results based on inspection or forensics. Various configurations and system configurations could be explored to target better administrative practices.
- Reconfigurable system software and tools for running rapid experiments on systems and networks that support dynamically changing topologies, varying protocols, flexible or malleable infrastructure, with possibly errant and buggy software. These system software and tools should also support high and low speed bandwidth interconnections. System performance may improve if the system is virtualized and studied with better configurability being the target optimization parameter.
- Trainable software and tools that learn correct, reliable, easy-to-use high performance, reliable configurations, such as topology, status, interconnection norms, patterns of behavior and parameters and that continuously improve and self-tune could be studied using virtualization. This technology could allow more stable configurations to be more quickly determined during periods of changing deployments or unpredicted external events.
- Self-composing methods of hiding the large scale nature of distributed systems consist of hierarchically organizing and/or self-composing interconnecting components. Emphasis is placed here in exploring how virtualization of operating systems services can be used to better support such capabilities. Maintenance and life-cycle issues are germane to the success of computer systems that are sustainable in the field, upgradeable, and have the potential for a long lifetime and, consequently, virtualization can be used to drive self composition and advance technology forward.
- Diagnosis to understand problems in the system, anomalies, and performance impediments, the ability to inspect the network using the construction of state-bearing snapshots and monitoring (see above) is essential. Being able to virtualize resources to focus on system improvements or to diagnose problems is essential in contemporary systems. Therefore, VCM uses virtualization as a methodology to enable such forensic or diagnostic capabilities. Diagnostics can be used to improve reliability, reduce vulnerabilities, and ascertain connectivity while improving usability. Inspection indicates the status of the system or network and helps management understand whether policies are succeeding or failing. Diagnostics that are effective use training (described above) that supports either learning techniques, or at a minimum, caching of important or useful configurations for re-use.

Cyber Physical Systems (CPS)

The CPS thematic area will support new, highly-innovative ideas for advancing design, analysis, and implementation of Cyber Physical Systems (CPS). CPS are physical and engineered systems whose operations are integrated, monitored, and controlled by a computational core. The computational core is embedded, typically demands response in bounded 'real' (physical) time, and is likely to be distributed and reconfigurable on-line.

The cyber and physical components of such systems cooperatively control system function, and they contribute jointly to properties such as real-time response, energy-consumption, and thermal load. Engineering for cyber-physical systems must account for the interacting and interdependent behaviors of both types of components to provide system-wide behavioral and property guarantees. Examples of CPS include medical devices and systems, defense systems, automobiles and intelligent highways, robotic manufacturing, avionics, and other critical physical infrastructures.

Currently, one-size-fits-all, real-time operating systems are not sufficient to support the challenges of this emerging class of distributed cyber-physical systems. The technology base upon which real-time systems currently are built is a chaotic mix of real-time operating systems, middleware, and general-purpose virtual machines. To address these challenges, this thematic area will support innovative concepts leading to a capable and coherent real-time technology base that includes semantically-

grounded, easily-integrated, configurable, and tailored systems software services. The aim is to completely re-think today's layered, "full-service" RTOS architectures and explore alternative principles for high-confidence system service composition at many scales.

Proposals are encouraged in three areas:

- Architecture and virtualization: This topic includes innovative systems services (spanning from platform- to application-level abstractions, systems software architectures and kernelization strategies, and virtual machine strategies) all of which contribute to a highly-configurable, open, safe and secure real-time technology framework.
- Composition and Integration: This topic seeks open, semantically-grounded composition technology and tools to support high-confidence configuration, integration, and tailoring of the CPS system services. Proposals may be submitted for innovative technologies that offer high potential to enable evidence-producing composition of assemblies of services. Critical issues include temporal integration, design for uncertainty, and fault-isolation in CPS. The goal is a new generation of design and implementation technology that can rigorously integrate services from a composeable technology base, yet enable certifiably dependable cyber-physical systems.
- Cyber-Physical Challenge Systems: A small number of 'future technology' incubation projects will be funded in CPS. These must propose system concepts for cyber and physical interaction (e.g., for biology and medicine, advanced materials and structures, transportation, and chemical processes), representing radical departures from current solutions, and having the potential to achieve dramatic improvements over today's embedded systems approaches and yield new product or cyber-enabled physical technology concepts.

Proposals may span more than one CPS topic. This is particularly encouraged in proposals that address both real-time systems software technology and the high-confidence design tools needed to soundly integrate the systems software services into dependable systems. Preliminary evaluation of proposed technology concepts should be a critical component of these proposals.

PIs with research and education interests whose scope is in Computer Systems Research but which do not fit within the four core areas or three thematic areas described above may contact a CSR Program Director for approval to submit a proposal. Such proposals will be designated to be part of a final category Other (OTH). Submission in this category requires Program Director approval as discussed in Section V.A.

On occasion, the CSR program will accept proposals for workshops and Small Grants for Exploratory Research (SGERs). These proposals may be submitted on or before the deadline for this solicitation under the conditions described herein, or they may be submitted at any other time in accordance with GPG guidelines. However, prior to submission of any workshop or SGER proposal, a PI must discuss their interests with a CSR Program Officer before submitting the proposal. Additional information about SGER proposals can be found in Section II.D.1. of the NSF Grant Proposal Guide (GPG).

III. AWARD INFORMATION

In terms of budget amount and team size of awards, the CSR program has three categories of awards, two for the core areas and one for the thematic areas:

CORE AREAS

Single Investigator and Small Group. These awards include one or two PIs, with budgets of up to $800,000, and award durations of two or three years. Approximately, 20 to 30 single investigator and small group awards are expected in each annual CSR competition, with an estimated average award size of approximately $450,000.

Team. These awards include three or more PIs, with budgets of up to $1,500,000, and award durations of three or four years. Approximately 3 to 6 team awards are expected in each annual CSR competition, with an estimated average award size of $900,000.

THEMATIC AREAS

Proposals in the thematic areas are expected to be one or two years in duration, should involve a few PIs, and will typically range between $200,000 and $400,000 in total funding. 20 to 30 awards are expected.

If a project requires computing equipment, or any other infrastructure in order to conduct the proposed activities, then such infrastructure may be requested. These items need to be listed in budget pages and a thorough justification must be provided

in the budget explanation section. If the infrastructure request is for more than $100,000, the PI should discuss the request with one of the Program Officers identified in this solicitation before submission of the proposal.

Estimated program budget, number of awards, and average award size/duration are subject to the availability of funds.

IV. ELIGIBILITY INFORMATION

Organization Limit:

None Specified

PI Limit:

None Specified

Limit on Number of Proposals per Organization:

None Specified

Limit on Number of Proposals per PI: 2

An individual may appear as PI, co-PI or Senior Personnel on no more than two proposals per annual CSR competition.

Additional Eligibility Info:

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Full Proposal Preparation Instructions: Proposers may opt to submit proposals in response to this Program Solicitation via Grants.gov or via the NSF FastLane system.

- Full proposals submitted via FastLane: Proposals submitted in response to this program 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 website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg. Paper copies of the GPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from pubs@nsf.gov. Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF 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.

- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov. The complete text of the NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: (http://www.nsf.gov/bfa/dias/policy/docs/grantsgovguide.pdf). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from pubs@nsf.gov.

In determining which method to utilize in the electronic preparation and submission of the proposal, please note the following:

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via the NSF FastLane system. Chapter II, Section D.3 of the Grant Proposal Guide provides additional information on collaborative proposals.

The following information supplements or deviates from the GPG or the NSF Grants.gov Application Guide

To assist NSF staff in sorting proposals for review, proposal titles should begin with "CSR---key" where key is an acronym for one of the CORE or THEMATIC areas. If a proposal addresses topics in more than one area, it should be directed to whichever one of the areas is most appropriate. Use the following acronyms to identify the appropriate area:

- EHS --- Embedded and Hybrid Systems
- PDOS --- Parallel and Distributed Operating Systems
- AES --- Advanced Execution Systems
- SMA --- System Modeling and Analysis
- CSI --- Cross-Systems Integration
- VCM --- Virtualization for Configuration Management
- CPS --- Cyber Physical Systems

For example, a proposal might have a title such as "CSR---PDOS: Resource Management in Peer to Peer Systems."

A workshop proposal should have the key "WORKSHOP", an SGER proposal should have the key "SGER", and a proposal that falls outside the CORE or THEMATIC areas described herein should use the key OTH. For proposals in these categories, PIs must contact one of the CSR Program Officers for permission to submit.

CSR proposals should describe how the project will yield significant research and education outcomes (e.g., by validating theories on real systems, by demonstrating the utility of new systems software and making it available to the community, and/or by disseminating and evaluating new educational materials or curricula).

Every proposal must include a discussion of Broader Impacts. Broader Impacts include the integration of education and research, promoting diversity in the computer systems workforce, developing substantial experimental research educational experiences, and developing curriculum and supporting materials in emerging computer systems areas. The following URL contains several examples of broader impacts activities: http://www.nsf.gov/pubs/2002/nsf022/bicexamples.pdf.

B. Budgetary Information

Cost Sharing: Cost sharing is not required by NSF in proposals submitted to the National Science Foundation.

C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. proposer's local time):

  January 17, 2007

  Second Friday in November, Annually Thereafter

D. FastLane/Grants.gov Requirements

- **For Proposals Submitted Via FastLane:**

  Detailed technical instructions regarding the technical aspects of preparation and submission via FastLane are available at: https://www.fastlane.nsf.gov/a1/newstan.htm. For FastLane user support, call the FastLane Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov. The FastLane Help Desk answers general technical questions related to the use of the FastLane system. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

  Submission of Electronically Signed Cover Sheets. The Authorized Organizational Representative (AOR) must electronically sign the proposal Cover Sheet to submit the required proposal certifications (see Chapter II, Section C of the Grant Proposal Guide for a listing of the certifications). The AOR must provide

the required electronic certifications within five working days following the electronic submission of the proposal. Further instructions regarding this process are available on the FastLane Website at: https://www.fastlane.nsf.gov/fastlane.jsp.

- **For Proposals Submitted Via Grants.gov:**

Before using Grants.gov for the first time, each organization must register to create an institutional profile. Once registered, the applicant's organization can then apply for any federal grant on the Grants.gov website. The Grants.gov's Grant Community User Guide is a comprehensive reference document that provides technical information about Grants.gov. Proposers can download the User Guide as a Microsoft Word document or as a PDF document. The Grants.gov User Guide is available at: http://www.grants.gov/CustomerSupport. In addition, the NSF Grants.gov Application Guide provides additional technical guidance regarding preparation of proposals via Grants.gov. For Grants.gov user support, contact the Grants.gov Contact Center at 1-800-518-4726 or by email: support@grants.gov. The Grants.gov Contact Center answers general technical questions related to the use of Grants.gov. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this solicitation.

Submitting the Proposal: Once all documents have been completed, the Authorized Organizational Representative (AOR) must submit the application to Grants.gov and verify the desired funding opportunity and agency to which the application is submitted. The AOR must then sign and submit the application to Grants.gov. The completed application will be transferred to the NSF FastLane system for further processing.

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

Proposals received by NSF are assigned to the appropriate NSF program and, if they meet NSF proposal preparation requirements, for review. All proposals are carefully reviewed by a scientist, engineer, or educator serving as an NSF Program Officer, and usually by three to ten other persons outside NSF who are experts in the particular fields represented by the proposal. These reviewers are selected by Program Officers charged with the oversight of the review process. Proposers are invited to suggest names of persons they believe are especially well qualified to review the proposal and/or persons they would prefer not review the proposal. These suggestions may serve as one source in the reviewer selection process at the Program Officer's discretion. Submission of such names, however, is optional. Care is taken to ensure that reviewers have no conflicts with the proposer.

A. NSF Merit Review Criteria

All NSF proposals are evaluated through use of the two National Science Board (NSB)-approved merit review criteria: intellectual merit and the broader impacts of the proposed effort. In some instances, however, NSF will employ additional criteria as required to highlight the specific objectives of certain programs and activities.

The two NSB-approved merit review criteria are listed below. The criteria include considerations that help define them. These considerations are suggestions and not all will apply to any given proposal. While proposers must address both merit review criteria, reviewers will be asked to address only those considerations that are relevant to the proposal being considered and for which the reviewer 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?

NSF staff will give careful consideration to the following 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.

B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by Adhoc Review 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.

After scientific, technical and programmatic review and consideration of appropriate factors, the NSF Program Officer recommends to the cognizant Division Director whether the proposal should be declined or recommended for award. NSF is striving to be able to tell applicants whether their proposals have been declined or recommended for funding within six months. The time interval begins on the date of receipt. The interval ends when the Division Director accepts the Program Officer's recommendation.

A summary rating and accompanying narrative will be completed and submitted 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 Officer. In addition, the proposer will receive an explanation of the decision to award or decline funding.

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 their 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 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.B. 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 (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 agreements also are administered in accordance with NSF

Cooperative Agreement Financial and Administrative Terms and Conditions (CA-FATC) and the applicable Programmatic Terms and Conditions. NSF awards are electronically signed by an NSF Grants and Agreements Officer and transmitted electronically to the organization via e-mail.

*These documents may be accessed electronically on NSF's Website at http://www.nsf.gov/awards/managing/general_conditions.jsp?org=NSF. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from pubs@nsf.gov.

More comprehensive information on NSF Award Conditions and other important information on the administration of NSF awards is contained in the NSF *Grant Policy Manual* (GPM) Chapter II, available electronically on the NSF Website at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpm.

C. Reporting Requirements

For all multi-year grants (including both standard and continuing grants), the Principal Investigator must submit an annual project report to the cognizant Program Officer at least 90 days before the end of the current budget period. (Some programs or awards require more frequent project reports). Within 90 days after expiration of a grant, the PI also is required to submit a final project report.

Failure to provide the required annual or final project reports will delay NSF review and processing of any future funding increments as well as any pending proposals for that PI. PIs should examine the formats of the required reports in advance to assure availability of required data.

PIs are required to use NSF's electronic project-reporting system, available through FastLane, for preparation and submission of annual and final project reports. Such reports provide information on activities and findings, project participants (individual and organizational) 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. Submission of the report via FastLane constitutes certification by the PI that the contents of the report are accurate and complete.

VIII. AGENCY CONTACTS

General inquiries regarding this program should be made to:

- Brett Fleisch, Program Director, 1175 N, telephone: (703) 292-4541, fax: (703) 292-9010, email: bfleisch@nsf.gov
- Frederica Darema, Senior Science and Technology Advisor, 1175 N, telephone: (703) 292-8950, fax: (703) 292-9010, email: fdarema@nsf.gov
- D. Helen Gill, Program Director, 1175 N, telephone: (703) 292-8950, fax: (703) 292-9010, email: hgill@nsf.gov

For questions related to the use of FastLane, contact:

- FastLane Help Desk, telephone: 1-800-673-6188; e-mail: fastlane@nsf.gov.

For questions relating to Grants.gov contact:

- Grants.gov Contact Center: If the Authorized Organizational Representatives (AOR) has not received a confirmation message from Grants.gov within 48 hours of submission of application, please contact via telephone: 1-800-518-4726; e-mail: support@grants.gov.

The primary Program Director contacts for the three THEMATIC areas are:

- Cross-Systems Integration: Frederica Darema
- Virtualization for Configuration Management: Brett Fleisch
- Cyber Physical Systems: D. Helen Gill

IX. OTHER INFORMATION

The NSF Website provides the most comprehensive source of information on NSF Directorates (including contact information), programs and funding opportunities. Use of this Website by potential proposers is strongly encouraged. In addition, MyNSF (formerly the Custom News Service)is an information-delivery system designed to keep potential proposers and other interested parties apprised of new NSF funding opportunities and publications, important changes in proposal and award policies and procedures, and upcoming NSF Regional Grants Conferences. Subscribers are informed through e-mail or the user's Web browser each time new publications are issued that match their identified interests. MyNSF also is available on NSF's Website at http://www.nsf.gov/mynsf/.

Grants.gov provides an additional electronic capability to search for Federal government-wide grant opportunities. NSF funding opportunities may be accessed via this new mechanism. Further information on Grants.gov may be obtained at http://www.grants.gov.

Related Programs:

RELATIONSHIP TO OTHER NSF PROGRAMS

Systems software exists in the context of applications, and it interacts with other software systems. Consequently, many projects will address topics described in this solicitation as well as topics covered in related programs.

The following NSF programs most closely overlap with the CSR program:

- Networking and Technology (NeTS);
- Cyber Trust (CT); and,
- Computing Processes and Artifacts (CPA).

If the major emphasis of the proposal is computer networks, then it should be submitted to the NeTS program.

If the major emphasis is to make systems more secure, then the proposal should be submitted to the CT program.

A proposal that develops or uses compiler technology for parallel, distributed and heterogeneous systems should be submitted to CSR, but a proposal that addresses theoretical compiler technology should be submitted to the CPA program.

Similarly, a project that develops programming languages for programming parallel applications should be submitted to CPA, whereas a project that develops systems software to support parallel computing should be submitted to CSR.

As other programs become active, PIs are encouraged to contact the cognizant Program Officers for discussion.

ABOUT THE NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) is an independent Federal agency created by the National Science Foundation Act of 1950, as amended (42 USC 1861-75). The Act states the purpose of the NSF is "to promote the progress of science; [and] to advance the national health, prosperity, and welfare by supporting research and education in all fields of science and engineering."

NSF funds research and education in most fields of science and engineering. It does this through grants and cooperative agreements to more than 2,000 colleges, universities, K-12 school systems, businesses, informal science organizations and other research organizations throughout the US. The Foundation accounts for about one-fourth of Federal support to academic institutions for basic research.

NSF receives approximately 40,000 proposals each year for research, education and training projects, of which approximately 11,000 are funded. In addition, the Foundation receives several thousand applications for graduate and

postdoctoral fellowships. The agency operates no laboratories itself but does support National Research Centers, user facilities, certain oceanographic vessels and Antarctic research stations. The Foundation also supports cooperative research between universities and industry, US participation in international scientific and engineering efforts, and educational activities at every academic level.

Facilitation Awards for Scientists and Engineers with Disabilities provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See Grant Proposal Guide Chapter II, Section D.2 for instructions regarding preparation of these types of proposals.

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 and (800) 281-8749, FIRS at (800) 877-8339.

The National Science Foundation Information Center may be reached at (703) 292-5111.

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 Website 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: (703) 292-7827
- **To Locate NSF Employees:** (703) 292-5111

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; and 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 proposer 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 or other entities needing information regarding applicants or nominees as part of a joint application review process, or in order to coordinate programs or policy; 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," 69 Federal Register 26410 (May 12, 2004), and NSF-51, "Reviewer/Proposal File and Associated Records, " 69 Federal Register 26410 (May 12, 2004). Submission of the information is voluntary. Failure to provide full and complete information, however, may reduce the possibility of receiving an award.

An agency may not conduct or sponsor, and a person is not required to respond to, an information collection unless it displays a valid Office of Management and Budget (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 the burden estimate and any other aspect of this collection of information, including suggestions for reducing this burden, to:

Suzanne H. Plimpton
Reports Clearance Officer
Division of Administrative Services
National Science Foundation
Arlington, VA 22230