Program Announcement
To DOE National Laboratories
LAB 04-13

Operating/Runtime Systems
for Extreme Scale Scientific Computation

SUMMARY: The Office of Advanced Scientific Computing Research (ASCR) of the Office of Science (SC), U.S. Department of Energy (DOE), hereby announce its interest in receiving proposals for research in the area of operating and runtime systems for extreme scale scientific computation. Partnerships among universities, National Laboratories, and industry are encouraged.

DATES: Researchers are requested to submit a letter of intent by March 26, 2004. This letter should include the name(s) of the participating institution(s), the Principal Investigator(s)/project director, the email address and address of the PI, the title of the project, the amount of funds requested, and a two- or three-page abstract. Letters of intent will be used to organize and expedite the merit review process. Failure to submit such letters will not negatively effect a responsive proposal submitted in a timely fashion. The letter of intent should be sent by E-mail to fjohnson@er.doe.gov, and the subject line should state: Letter-of-Intent regarding Program Announcement LAB 04-13.

Formal proposals submitted in response to this announcement must be received by DOE no later than 4:30 p.m., May 4, 2004. Electronic submission of formal proposals in PDF format is encouraged.

ADDRESSES: Letters of Intent should be sent by E-mail to Dr. Frederick Johnson at fjohnson@er.doe.gov, and the subject line should state: Letter-of-Intent regarding Program Announcement LAB 04-13.

Formal proposals, referencing Program Announcement LAB 04-13, should also be submitted by E-mail to: Dr. Frederick Johnson at fjohnson@er.doe.gov. If necessary, proposals may be submitted on CD-ROM to Dr. Frederick Johnson, U.S. Department of Energy, Office of Advanced Scientific Computing Research, SC-31/Germantown Building, 1000 Independence Avenue, SW, Washington DC 20585-1290. ATTN: Program Announcement LAB 04-13.

When submitting proposals by U.S. Postal Service Express Mail, any commercial mail delivery service, or when hand carried by the proposer, the following address must be used: U.S. Department of Energy, Office of Advanced Scientific Computing Research, SC-31, 19901 Germantown Road, Germantown, MD 20874-1290, ATTN: Program Announcement LAB 04-13.

FOR FURTHER INFORMATION CONTACT: Dr. Frederick Johnson, Office of Advanced Scientific Computing Research, SC-31/Germantown Building, U.S. Department of Energy, 1000

Independence Ave. SW, Washington, DC 20585-1290. Telephone number and e-mail address are:

Dr. Frederick Johnson: telephone (301) 903-3601, e-mail: fjohnson@er.doe.gov

SUPPLEMENTARY INFORMATION:

The Forum to Address Scalable Technologies for Runtime and Operating Systems (FAST-OS) has conducted a series of workshops focused on issues associated with operating and runtime systems for very large computing systems used for high end scientific modeling and simulation. This workshop series was sponsored by the Office of Advanced Scientific Computing Research of the DOE Office of Science. The most recent workshop was held in July 2003, and the final report, together with other results of the workshop series may be found at: http://www.cs.unm.edu/~fastos. An interagency workshop, the Workshop on the Roadmap for the Revitalization of High-End Computing was held in June of 2003. Section 5 of the workshop report addresses runtime and operating systems. The charter of the researchers that produced this section was to establish baseline capabilities required in the operating systems for projected High-End Computing systems scaled to the end of this decade and determine the critical advances that must be undertaken to meet these goals. The report is available at: http://www.itrd.gov/hecrtf-outreach/20040112_cra_hecrtf_report.pdf.

Background: Operating and Runtime Systems (OS/R)

Operating and runtime systems provide mechanisms to manage system hardware and software resources for the efficient execution of large scale scientific applications. They are essential to the success of both large scale systems and complex applications. By the end of this decade petascale computers with thousands of times more computational power than any in current use will be vital tools for expanding the frontiers of science and for addressing vital national priorities. These systems will have tens to hundreds of thousands of processors, an unprecedented level of complexity, and will require significant new levels of scalability and fault management. The overwhelming size and complexity of such systems poses deep technical challenges that must be overcome to fully exploit their potential for scientific discovery.

Applications require multiple services from OS/R layers, including: resource management and scheduling, fault-management (detection, prediction, recovery, and reconfiguration), configuration management, and file systems access and management. Current and future large-scale parallel systems require that such services be implemented in a fast and scalable manner so that the OS/R does not become a performance bottleneck. The current trend in large-scale scientific systems is to leverage operating systems developed for other areas of computing – operating systems that were not specifically designed for large-scale, parallel computing platforms. Unix, Linux and other Unix derivatives are the most popular OS's in use for high end scientific computing, and these all reflect a technological heritage nearly 30 years old with no fundamental mechanisms to support parallel systems.

Without reliable, robust operating systems and runtime environments the computational science research community will be unable to easily and completely employ future generations of extreme systems for scientific discovery. The application research community will miss

important scientific opportunities in areas such as computational fusion, nanotechnology, and computational biology that are on the threshold of rapid advance through the innovative use of extreme-scale scientific computation. New investments in both basic and applied research are required to maintain the creative pace established by terascale computation for scientific discovery.

Background: High-End Computing Revitalization Task Force (HECRTF) and Academic Research

During the past summer, several federal agencies with interests in high performance computing participated in the HECRTF and developed a plan for future government investments in high-end computing. As part of this plan a renewed emphasis has been placed on coordination of federally-funded research in this area. As a major contributor to the HECRTF activity, the Office of Science is a leading participant in the coordination of research investments. The research activities described in this Announcement have been coordinated with participating HECRTF research agencies, and this coordination will continue throughout the lifetime of the research activities. Additional information on the HECRTF may be found at: http://www.itrd.gov/hecrtf-outreach/index.html.

The Opportunity and the Challenge

By the end of this decade extreme scale systems will be available that are based on a variety of challenging architectures ranging from distributed memory clusters of unprecedented scale to the systems resulting from the DARPA High Productivity Computing Systems program that are likely to be based upon innovative architectural concepts, such as PIMs, FPGAs, and complex memory hierarchies that have no analog in today's terascale systems. Systems with tens to hundreds of thousands of processors and new architectural concepts will differ greatly in scale and complexity from today's systems, and this difference will place new and very difficult challenges on OS/R design and implementation.

There are many fundamental questions in operating system and runtime research that must be explored in order to enable scientific application developers and users to achieve maximum effectiveness and efficiency on this new generation of systems, including (but not limited to):

- **Ease of use.** Application users need a coherent, cohesive picture of these huge systems – they need to be able to look at jobs running on 100,000 processors in a meaningful way.
- **Support for architectural innovation.** Current operating systems often limit hardware innovation through the use of a hardware abstraction layer that cannot support innovative hardware paradigms.
- **Dynamic support for multiple management policies.** Current operating systems limit application development through the use of fixed resource management policies rather than dynamic policies responsive to changing application needs.
- **Leveraging mainstream technology.** Strategies are needed that enable OS/R systems developed to meet specialized needs of the HEC community to leverage the talents and technology development of the mainstream open source OS community.

- **Support for fault tolerance.** Extreme scale systems will require innovative new approaches to OS/R support for fault detection and management. Interrupts are likely to be the norm rather than the exception during any lengthy application run.
- **Rethinking the OS in terms of scalability and usability.** We need to determine how HPC requirements differ from those of general computing. HPC requirement differences will surely continue to dictate innovation in both OS structure and exported interfaces.
- **Scalability of operating systems** What should an operating system for a hundred thousand processor machine look like? Is a hierarchical approach best? How can the operating system make a fundamentally unreliable machine, in which some components are always broken, continue to effectively function?
- **Self awareness and optimization.** How can an extreme scale system (hardware and software) monitor and adapt to meet changing requirements of long running applications?

Technical challenges such as these represent an opportunity for basic and applied research to provide new insights into mechanisms for harnessing the potential of next generation extreme-scale systems.

Investment Plan of the Office of Science

The Secretary of Energy recently released a twenty year vision and plan for research facilities in the Office of Science in the document, Facilities for the Future of Science: A Twenty-Year Outlook. A copy of the plan may be found at: http://www.sc.doe.gov/Sub/Facilities_for_future/20-Year-Outlook-screen.pdf. The plan contains a prioritized list of new research facilities, and the number two priority is an UltraScale Scientific Computing Capability (USSCC), which will increase by at least a factor of 100 the computing capability available to support open scientific research and which will reduce from years to days the time required to simulate complex systems of interest to the Department. When fully realized, the computing capability of the USSCC will enable computation-based scientific advances that are unachievable by current large- scale computing systems. USSCC systems will place new and critical demands on operating systems and runtime environments to support complex applications and enable these systems to reach their full potential. The research supported by this announcement is a critical step towards developing OS and runtime systems able to meet these needs.

Solicitation Emphasis

This announcement is focused on research and development of operating and runtime systems which enable the effective management and use of extreme-scale systems (petascale and above) for scientific computation. The overall goal of this announcement is to stimulate research and development related to operating and runtime systems for petascale systems the in 2010 timeframe. It is likely that these systems will include a combination of commodity and custom components, with different systems reflecting different degrees of customization. The research into runtime and operating systems must be driven from the needs of current and future applications. The primary focus is on the supporting the needs of existing and anticipated SC and other DOE applications; however, the resulting systems should address issues related to the broader HEC code base. An ultimate and perhaps idealistic goal would be to develop a unified

runtime and operating system that could fully support and exploit petascale and beyond systems and autonomously adapt for performance, upgrades, security, and fault tolerance. The activities supported by this announcement may be a combination of basic and applied research, development, prototyping, testing and ultimately deployment.

Example Research Topics

Runtime and operating systems provide the glue that bind running applications to hardware. The research activities supported by this activity need to bridge the gap between new languages and/or programming models and next-generation hardware, including interactions with novel architectures. Consequently, there are a wide variety of research topics that are appropriate for this effort. A brief listing of candidate topics is provided below, but research in other relevant areas and combinations of areas is encouraged:

- **Virtualization.** A key aspect of OS/R systems is that they provide "virtual devices." Virtualization must balance ease of use by detail hiding vs achieving scalability and performance by exploiting details.
- **Adaptation.** Traditionally, runtime and operating systems have been designed to provide a fixed set of services and to provide a single implementation for each of these services. Future runtime and operating systems will need to provide different sets of services and/or different implementations of these services based on the needs of applications and/or characteristics of the underlying system.
- **Usage models.** Large machines have typically been used in batch mode. Other modes of operation, including interactive usage for computational steering will also need to be supported in the future.
- **Metrics.** Metrics, benchmarks, and test suites are needed to evaluate progress and guide design. Challenges include determining what to measure and how to generate understandable analyses. Benchmarks and test suites must accurately reflect the needs of applications.
- **Support for fault handling in OS and run-time.** Many jobs will encounter an interrupt in service during their execution. Research is needed to address all aspects of fault tolerance, including fault detection, anticipation, management and tolerance. Research in checkpointing systems is also needed.
- **Memory hierarchy management.** It is clear that the memory hierarchy is going to become deeper and/or more complex. Applications will need significantly improved support for managing memory.
- **Security.** Scalable security mechanisms are needed to support new authorization, authentication and access control requirements.
- **Common API.** Research in common runtime/OS API's is required to greatly enhance application portability and ease the introduction of new systems. The current POSIX standard has been beneficial to the general community, but it is lacking in the support of high-end systems.
- **Scalable, single-system image.** In principle, the ability to treat a very large system as a single system has many advantages and provides significant simplifications from an end user perspective. However, it is not clear what the technical trade-offs are for single system image technology at extreme scale, and additional research is needed.

- **Parallel and Network I/O.** Some classes of future HEC systems will have specialized interconnect fabrics to provide communications and data movement among processors or groups of processors or storage devices. Operating systems and/or runtime systems will be required to share, schedule, and control these resources.
- **OS Support for efficient interprocessor communication.** Standard OS's do not recognize the concept of a parallel job. Support is needed for global operations which minimize local variations and avoid degradation of performance for the whole job.
- **Light-weight low-level communication paradigms.** Research in light-weight and low level communication mechanisms is needed to improve scalability and performance.

Community building

An important goal of this announcement is to foster the development of an active research community in operating systems and runtime environments for high end systems. In order to meet this goal the following are mandatory requirements for awardees:

- All developed code must be released under the most permissive open source license possible. This is to enable other researchers and vendors to build upon research successes with a minimum of intellectual property issues.
- Each research team should plan to send representatives to annual or semi-annual PI meetings and give presentations on the status and promise of their research. Meeting attendees will include invited participates from other relevant research communities, including the Linux community. Objectives of these meetings are to foster a sense of community and serve as a venue for exchange of information. These meetings will also serve as a means to exchange information on complementary programs including the DARPA HPCS program, NNSA ASC program and SciDAC.

Frameworks and Novel Approaches

Operating system and runtime research often requires a large overhead of supporting infrastructure code, such as device drivers, that must be developed before undertaking the core ideas of the research. This may be alleviated if an existing OS framework, such as Linux, K42, or Plan9, is chosen as a base of the research. Responses to this announcement may choose to use an existing framework for their OS/Runtime research or they may propose to develop a new framework as part of the research activity. Any proposed new framework must be described and discussed at the community PI meetings. Smaller novel approaches are also encouraged.

Testbed Strategy

Testbeds are essential to the future of the research sponsored by this announcement, and the development of an effective testbed strategy is an important overall objective. Each proposal should contain a section which discusses the characteristics of the test environments necessary for the research and identify the time frames in which specific testbed support will be required.

Collaboration

Researchers are encouraged to collaborate with researchers in other institutions, such as universities, industry, non-profit organizations, federal laboratories and Federally Funded Research and Development Centers (FFRDCs), including the DOE National Laboratories, where appropriate, and to include cost sharing wherever feasible. Additional information on collaboration is available in the Application Guide for the Office of Science Financial Assistance Program that is available via the Internet at: http://www.sc.doe.gov/production/grants/Colab.html.

Program Funding

It is anticipated that up to $4 million annually will be available for multiple awards for this program. Initial awards will be made late in Fiscal Year 2004 or early Fiscal Year 2005, in the categories described above, and proposals may request project support for up to three years. All awards are contingent on the availability of funds and programmatic needs. Annual budgets for successful projects are expected to range from $500,000 to $1,500,000 per project although smaller projects of exceptional merit may be considered. Annual budgets may increase in the out-years but should remain within the overall annual maximum guidance. Any proposed effort that exceeds the annual maximum in the out- years should be separately identified for potential award increases if additional funds become available. DOE is under no obligation to pay for any costs associated with the preparation or submission of proposals if an award is not made.

Submission Information

The Project Description must be 25 pages or less, exclusive of attachments. It must contain an abstract or project summary on a separate page with the name of the principal investigator, mailing address, phone, FAX, and email listed. The proposal must include letters of intent from non-funded collaborators (briefly describing the intended contribution of each to the research), and short curriculum vitae for the principal investigator and any co-PIs.

The instructions and format described below should be followed. Reference Program Announcement LAB 04-13 on all submissions and inquiries about this program.

OFFICE OF SCIENCE
GUIDE FOR PREPARATION OF SCIENTIFIC/TECHNICAL PROPOSALS TO BE SUBMITTED BY NATIONAL LABORATORIES

Proposals from National Laboratories submitted to the Office of Science (SC) as a result of this program announcement will follow the Department of Energy Field Work Proposal process with additional information requested to allow for scientific/technical merit review. The following guidelines for content and format are intended to facilitate an understanding of the requirements necessary for SC to conduct a merit review of a proposal. Please follow the guidelines carefully, as deviations could be cause for declination of a proposal without merit review.

1. Evaluation Criteria Proposals will be subjected to scientific merit review (peer review) and will be evaluated against the following criteria, which are listed in descending order of importance:

1. Scientific and/or technical merit of the project;

2. Appropriateness of the proposed method or approach;

3. Competency of the researcher's personnel and adequacy of the proposed resources; and

4. Reasonableness and appropriateness of the proposed budget.

The evaluation under the first criterion, Scientific and Technical Merit, will pay particular attention to:

a) The potential of the proposed project to make a significant impact in operating systems and runtime research.
b) The demonstrated capabilities of the researchers to perform basic research related to operating systems/runtime and transform these research results into software that can be widely deployed.
c) The likelihood that the methodologies and software components that result from this effort will have a substantial impact on the operating system research and vendor community outside of the projects.

The evaluation under item 2, Appropriateness of the Proposed Method or Approach, will also consider the following elements related to quality of planning and management:

a) Quality of the plan for effective coupling of operating system and runtime research, with application needs and transition to testbed environments.
b) Quality and clarity of proposed work schedule and deliverables.
c) Quality of the proposed approach to intellectual property management and open source licensing.

Note that external peer reviewers are selected with regard to both their scientific expertise and the absence of conflict-of-interest issues. Non-federal reviewers may be used, and submission of an proposal constitutes agreement that this is acceptable to the investigator(s) and the submitting institution.

The evaluation will also include program policy factors such as the relevance of the proposed research to the terms of the announcement, the uniqueness of the proposer's capabilities, and prior performance on DOE funded work.

2. Summary of Proposal Contents

Field Work Proposal (FWP) Format (Reference DOE Order 5700.7C) (DOE ONLY)
Proposal Cover Page
Table of Contents
Abstract
Narrative
Literature Cited
Budget and Budget Explanation
Other support of investigators
Biographical Sketches

Description of facilities and resources
Appendix

2.1 Number of Copies to Submit

Formal proposals, referencing Program Announcement LAB 04-13, should also be submitted by E-mail to: Dr. Frederick Johnson at fjohnson@er.doe.gov. If necessary, proposals may be submitted on CD-ROM to Dr. Frederick Johnson, U.S. Department of Energy, Office of Advanced Scientific Computing Research, SC-31/Germantown Building, 1000 Independence Avenue, SW, Washington DC 20585-1290. ATTN: Program Announcement LAB 04-13.

3. Detailed Contents of the Proposal

Proposals must be readily legible, when photocopied, and must conform to the following three requirements: the height of the letters must be no smaller than 10 point with at least 2 points of spacing between lines (leading); the type density must average no more than 17 characters per inch; the margins must be at least one-half inch on all sides. Figures, charts, tables, figure legends, etc., may include type smaller than these requirements so long as they are still fully legible.

3.1 Field Work Proposal Format (Reference DOE Order 5700.7C) (DOE ONLY)

The Field Work Proposal (FWP) is to be prepared and submitted consistent with policies of the investigator's laboratory and the local DOE Operations Office. Additional information is also requested to allow for scientific/technical merit review.

Laboratories may submit proposals directly to the SC Program office listed above. A copy should also be provided to the appropriate DOE operations office.

3.2 Proposal Cover Page

The following proposal cover page information may be placed on plain paper. No form is required.

Title of proposed project
SC Program announcement title
Name of laboratory
Name of principal investigator (PI)
Position title of PI
Mailing address of PI
Telephone of PI
Fax number of PI
Electronic mail address of PI
Name of official signing for laboratory*
Title of official
Fax number of official
Telephone of official

Electronic mail address of official
Requested funding for each year; total request
Use of human subjects in proposed project:

If activities involving human subjects are not planned at any time during the proposed project period, state "No"; otherwise state "Yes", provide the IRB Approval date and Assurance of Compliance Number and include all necessary information with the proposal should human subjects be involved.

Use of vertebrate animals in proposed project:

If activities involving vertebrate animals are not planned at any time during this project, state "No"; otherwise state "Yes" and provide the IACUC Approval date and Animal Welfare Assurance number from NIH and include all necessary information with the proposal.

Signature of PI, date of signature
Signature of official, date of signature*

*The signature certifies that personnel and facilities are available as stated in the proposal, if the project is funded.

3.3 Table of Contents

Provide the initial page number for each of the sections of the proposal. Number pages consecutively at the bottom of each page throughout the proposal. Start each major section at the top of a new page. Do not use unnumbered pages and do not use suffices, such as 5a, 5b.

3.4 Abstract

Provide an abstract of no more than 250 words. Give the broad, long-term objectives and what the specific research proposed is intended to accomplish. State the hypotheses to be tested. Indicate how the proposed research addresses the SC scientific/technical area specifically described in this announcement.

3.5 Narrative

The narrative comprises the research plan for the project and is limited to 5 pages per task. It should contain the following subsections:

Background and Significance: Briefly sketch the background leading to the present proposal, critically evaluate existing knowledge, and specifically identify the gaps which the project is intended to fill. State concisely the importance of the research described in the proposal. Explain the relevance of the project to the research needs identified by the Office of Science. Include references to relevant published literature, both to work of the investigators and to work done by other researchers.

Preliminary Studies: Use this section to provide an account of any preliminary studies that may be pertinent to the proposal. Include any other information that will help to establish the

experience and competence of the investigators to pursue the proposed project. References to appropriate publications and manuscripts submitted or accepted for publication may be included.

Research Design and Methods: Describe the research design and the procedures to be used to accomplish the specific aims of the project. Describe new techniques and methodologies and explain the advantages over existing techniques and methodologies. As part of this section, provide a tentative sequence or timetable for the project.

Subcontract or Consortium Arrangements: If any portion of the project described under "Research Design and Methods" is to be done in collaboration with another institution, provide information on the institution and why it is to do the specific component of the project. Further information on any such arrangements is to be given in the sections "Budget and Budget Explanation", "Biographical Sketches", and "Description of Facilities and Resources".

3.6 Literature Cited

List all references cited in the narrative. Limit citations to current literature relevant to the proposed research. Information about each reference should be sufficient for it to be located by a reviewer of the proposal.

3.7 Budget and Budget Explanation

A detailed budget is required for the entire project period, which normally will be three years, and for each fiscal year. It is preferred that DOE's budget page, Form 4620.1 be used for providing budget information*. Modifications of categories are permissible to comply with institutional practices, for example with regard to overhead costs.

A written justification of each budget item is to follow the budget pages. For personnel this should take the form of a one-sentence statement of the role of the person in the project. Provide a detailed justification of the need for each item of permanent equipment. Explain each of the other direct costs in sufficient detail for reviewers to be able to judge the appropriateness of the amount requested.

Further instructions regarding the budget are given in section 4 of this guide.

* Form 4620.1 is available at web site: http://www.sc.doe.gov/production/grants/Forms-E.html

3.8 Other Support of Investigators

Other support is defined as all financial resources, whether Federal, non-Federal, commercial or institutional, available in direct support of an individual's research endeavors. Information on active and pending other support is required for all senior personnel, including investigators at collaborating institutions to be funded by a subcontract. For each item of other support, give the organization or agency, inclusive dates of the project or proposed project, annual funding, and level of effort devoted to the project.

3.9 Biographical Sketches

This information is required for senior personnel at the laboratory submitting the proposal and at all subcontracting institutions. The biographical sketch is limited to a maximum of two pages for each investigator.

3.10 Description of Facilities and Resources

Describe briefly the facilities to be used for the conduct of the proposed research. Indicate the performance sites and describe pertinent capabilities, including support facilities (such as machine shops) that will be used during the project. List the most important equipment items already available for the project and their pertinent capabilities. Include this information for each subcontracting institution, if any.

3.11 Appendix

Include collated sets of all appendix materials with each copy of the proposal. Do not use the appendix to circumvent the page limitations of the proposal. Information should be included that may not be easily accessible to a reviewer.

Reviewers are not required to consider information in the Appendix, only that in the body of the proposal. Reviewers may not have time to read extensive appendix materials with the same care as they will read the proposal proper.

The appendix may contain the following items: up to five publications, manuscripts (accepted for publication), abstracts, patents, or other printed materials directly relevant to this project, but not generally available to the scientific community; and letters from investigators at other institutions stating their agreement to participate in the project (do not include letters of endorsement of the project).

4. Detailed Instructions for the Budget

(DOE Form 4620.1 "Budget Page" may be used)

4.1 Salaries and Wages

List the names of the principal investigator and other key personnel and the estimated number of person-months for which DOE funding is requested. Proposers should list the number of postdoctoral associates and other professional positions included in the proposal and indicate the number of full-time-equivalent (FTE) person-months and rate of pay (hourly, monthly or annually). For graduate and undergraduate students and all other personnel categories such as secretarial, clerical, technical, etc., show the total number of people needed in each job title and total salaries needed. Salaries requested must be consistent with the institution's regular practices. The budget explanation should define concisely the role of each position in the overall project.

4.2 Equipment

DOE defines equipment as "an item of tangible personal property that has a useful life of more than two years and an acquisition cost of $25,000 or more." Special purpose equipment means equipment which is used only for research, scientific or other technical activities. Items of needed equipment should be individually listed by description and estimated cost, including tax, and adequately justified. Allowable items ordinarily will be limited to scientific equipment that is not already available for the conduct of the work. General purpose office equipment normally will not be considered eligible for support.

4.3 Domestic Travel

The type and extent of travel and its relation to the research should be specified. Funds may be requested for attendance at meetings and conferences, other travel associated with the work and subsistence. In order to qualify for support, attendance at meetings or conferences must enhance the investigator's capability to perform the research, plan extensions of it, or disseminate its results. Consultant's travel costs also may be requested.

4.4 Foreign Travel

Foreign travel is any travel outside Canada and the United States and its territories and possessions. Foreign travel may be approved only if it is directly related to project objectives.

4.5 Other Direct Costs

The budget should itemize other anticipated direct costs not included under the headings above, including materials and supplies, publication costs, computer services, and consultant services (which are discussed below). Other examples are: aircraft rental, space rental at research establishments away from the institution, minor building alterations, service charges, and fabrication of equipment or systems not available off- the-shelf. Reference books and periodicals may be charged to the project only if they are specifically related to the research.

a. Materials and Supplies

The budget should indicate in general terms the type of required expendable materials and supplies with their estimated costs. The breakdown should be more detailed when the cost is substantial.

b. Publication Costs/Page Charges

The budget may request funds for the costs of preparing and publishing the results of research, including costs of reports, reprints page charges, or other journal costs (except costs for prior or early publication), and necessary illustrations.

c. Consultant Services

Anticipated consultant services should be justified and information furnished on each individual's expertise, primary organizational affiliation, daily compensation rate and number of

days expected service. Consultant's travel costs should be listed separately under travel in the budget.

d. Computer Services

The cost of computer services, including computer-based retrieval of scientific and technical information, may be requested. A justification based on the established computer service rates should be included.

e. Subcontracts

Subcontracts should be listed so that they can be properly evaluated. There should be an anticipated cost and an explanation of that cost for each subcontract. The total amount of each subcontract should also appear as a budget item.

4.6 Indirect Costs

Explain the basis for each overhead and indirect cost. Include the current rates.