

**Program Announcement
To DOE National Laboratories
LAB 10-264**

***High-Capacity Optical Networking
and Deeply Integrated Middleware Services for Distributed
Petascale Science***

SUMMARY:

The Office of Advanced Scientific Computing Research (ASCR) of the Office of Science (SC) at the U.S. Department of Energy (DOE) advances world-class high-performance computing research and facilities to accelerate scientific discoveries in support of DOE mission. ASCR hereby announces its interest in receiving peer-reviewable Field Work Proposals (FWPs) for potential funding of advanced networking/middleware projects in two technical areas: 1) intelligent Terabits (Tbits/s) optical networks and 2) deeply integrated middleware services. Intelligent Terabits networking is an agile infrastructure capable of delivering differentiated quality of service networking, on-demand dedicated bandwidth, and unprecedented end-to-end performance to distributed data-intensive petascale - exascale science applications. Deeply integrated middleware consists of the software libraries and APIs that will provide scientists and researchers with effective access to the advanced capabilities of intelligent Terabits optical networks, simplify multi-domain security and authentication problems, and enhance the functionality and usability of network- attached computers. Intelligent optical networks with deeply integrated middleware services will enable the delivery of end-to-end performance that far outstrips what is possible over today's Internet.

This funding will lead to the development and deployment of advanced ultra high-speed networking technologies and middleware services for the distribution of massive data sets. This Program Announcement has three major elements that must be addressed by potential applicants; 1) develops intelligent networking technologies and related deeply integrated middleware services that work effectively at 100 Gbits/s speeds; 2) leverages DOE's recently deployed DOE's 100 Gbits/s network demonstration prototype, and 3) includes development of a well-defined plan to test and validate the proposed technologies and/ or services on DOE's networking infrastructure (ESnet) and related systems. DOE's high-performance network and experimental networking facilities called ESnet (Energy Sciences Networks - (<http://www.es.net/>)) are operated by Lawrence Berkeley National Laboratory.

DATES:

Full proposals submitted in response to this Announcement must be received no later than 8:00 pm ET, Friday, April 23, 2010, to be accepted for merit review and to permit timely consideration for award in Fiscal Year 2010.

Please see the "Addresses" section below for further instructions on the method of submission for the proposal.

ADDRESSES and SUBMISSION INSTRUCTIONS:

Have your LAB administrator submit the entire LAB proposal and FWP via Searchable FWP (<https://www.osti.gov/fwp>). If you have questions about who your LAB administrator is or how to use Searchable FWP, please contact the Searchable FWP Support Center. Please submit, via Federal Express, a single PDF file of the entire LAB proposal and FWP on a CD along with two hard copies to the address below. This will assist in expediting the review process.

Please send the CD and 2 hard copies via Federal Express to:

Teresa Beachley
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Office of Science
19901 Germantown Road
Germantown, MD 20874-1290
ATTN: Program Announcement LAB 10-264

FOR FURTHER INFORMATION CONTACT:

A) High-Capacity Optical Networks

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SUPPLEMENTARY INFORMATION:

Background:

The Office of Advanced Scientific Computing Research in DOE provides world-class leadership in developing and deploying computational and networking capabilities to analyze, model, simulate, and predict complex phenomena important to the nation. A particular challenge of

ASCR is providing state-of-the-art networking technologies and novel middleware software to support extreme-scale distributed computing and large-scale experiments that generate massive data sets. DOE scientists continuously push the limits of today's Internet and are ready to explore the realm of advanced networks that can deliver a 1000 fold increase in end-to-end throughput to distribute massive data sets. Advanced network infrastructures with these capabilities will be expected to be 1) agile - to support dynamic reconfiguration needed to support a wide range of high-end applications with unique end-to-end performance requirements; 2) intelligent - to facilitate automation of middleware services to enable ease-of-use of advanced network capabilities for scientists; 3) observable and controllable - to advance end-to-end performance and fault monitoring; and 4) ultra fast - by exploring the emerging 100 Gbits/s link technologies to deliver multi-gigabit throughput to high-end data intensive applications.

A) High-Capacity Networks

High-capacity networks have emerged as critical components of modern scientific infrastructures. High-capacity networks are used to collect, store, and share the massive science data sets generated by extreme-scale computing and large-scale science experiments such as the Large Hadron Collider. As these trends continue and massive science data becomes critical to scientific discoveries, networks with unprecedented end-to-end performance and agility will be needed to support distributed data-intensive science activities. The current priorities that address the development, deployment, and operation of high-capacity networks for distributed data-intensive science are summarized in four technical areas described below: 1) hybrid packet/circuit-switched networks, 2) multi-layer multi-domain dynamic provisioning, 3) 100 Gbps system-level network components and services, and 4) multi-layer multi-domain network Measurement and Monitoring. Potential applicants interested in addressing the above networking challenges must ensure that the proposed solutions work efficiently at 100 Gbps speeds with a plan to test and validate the resulting work on DOE experimental networking infrastructures.

B) Deeply integrated Middleware services

Deeply integrated middleware services provide a suite of functional libraries and APIs that simplify the task of creating and operating complex multi-domain network environments, and reduce the need for scientists to understand those operational details. For example, network measurement services need a mechanism to discover, and align with, the monitoring components of the intelligent network infrastructure; similarly, analysis services need to locate archived datasets. Both researchers and code developers need simple APIs to build the agile services needed in these multi-domain environments. Agile middleware libraries and APIs built on an appropriate abstraction framework, in turn, simplify the creation of application-specific tools and services.

To develop networks with these advanced capabilities, DOE intends to build on its advanced network demonstration prototype based on 100 Gbits/s links funded through the American Recovery and Re-investment Act (ARRA) of 2009.

This announcement solicits research and development projects to address the above challenges in four critical and high priority technical areas:

- **Hybrid packet/circuit-switched networks.** A hybrid networking paradigm combines traditional packet and circuit switching concepts over a single integrated backbone network to provide differentiated network services to high-end science applications with different end-to-end networking performance requirements. FWPs are sought to address (a) networking challenges of hybrid networks. These include but are not limited to the following: dynamic allocation of resources across multiple networking modes, hybrid networking traffic engineering services and inter-domain peering services, and protection and recovery mechanisms for hybrid networks. (b) middleware challenges of creating hybrid networks. These include but are not limited to the following: functions to allow the provisioning, optimization, and management of hybrid networks by science applications, functions to expose network capabilities, and functions to securely access the network control plane.
- **Multi-Layer Multi-Domain Dynamic Provisioning.** Recent advances in transport network technologies offers new opportunities to develop novel network services such as on-demand circuits, scheduled circuits, guaranteed end-to-end bandwidth, and network virtualization at different layers using VLANs. The realization of these capabilities will require new end-to-end network signaling and provisioning schemes beyond traditional MPLS and GMPLS. These new schemes must work effectively across multiples network layers and across different autonomous network domains. FWPS are sought to (a) develop dynamic provisioning of on-demand bandwidth and circuits at different network layers, including but not limited to advanced tools for managing and monitoring network provisioning services; automated services to co-schedule application resources with network provisioning; technologies to extend backbone provisioning capabilities to site/campus LANs; and techniques to provide network restoration and protection to provisioned bandwidth/circuits; (b) authentication and authorization (AA) services, functions to simplify application access to higher level AA services, functions to expose provisioning capabilities, functions to allow applications to request these services, and mechanisms to automate the creation of these services.
- **100 GE System-Level Network Components and Services.** The deployment of the 100 GigE-based network demonstration prototype provides network researchers new opportunities to address Tbits/sec networking challenges and to support the distribution of massive science data in DOE. At these speeds, conventional networking hardware, network management tools and services, security systems, network-aware middleware, and host system stacks may not scale efficiently. FWPs are sought in this technical area to develop or scale existing system-level network technologies to work efficiently with 100 GigE technologies. These include but are not limited to SANs and WANs 100 GigE-based data transfer protocols; 100GigE IDS and DPI systems, programmable network interface, host provisioning software for packets/circuit services, network-application APIs, etc. Respondents are encouraged to leverage DOE's 100 GigE network demonstration prototype in formulating their proposed research along with a plan to use the testbed for performance testing and validation.
- **Multi-Layer Multi-Domain Network Measurement and Monitoring** The ability to monitor and predict the end-to-end performance and faults in high-performance networks is critical to high-end science applications. FWPs with innovative approaches to fault diagnostics, performance measurement and prediction, and related network management are sought to provide services that enable scientists to make effective use of network

resources, especially at 100 Gbits/s speeds. These include but are not limited to (a) scalable and secure tools and services for end-to-end circuit monitoring; end system host software stack application environment monitoring tools; services for multi-layer inter-domain network monitoring; and services to co-schedule end-to end network monitoring with network-aware data-intensive applications; (b) statistical techniques for analyzing and visualizing network measurement data, functions to simplify access to higher level AA services, and functions to expose measurement/monitoring tools, data, and services. Respondents are encouraged to leverage the PerfSONAR framework and the DOE's 100 GigE network demonstration prototype to formulate their proposed research and to develop a plan to use these facilities for performance testing and validation.

Additional Information

DOE operates a high-performance wide area best-effort IP backbone called ESnet (<http://www.es.net/>) and a switched Science Data Network (SDN) (<http://www.nitrd.gov/subcommittee/lsn/jet/material/ESnet4-JET.pdf>) network both operated by Lawrence Berkeley National Laboratory (<http://www.lbl.gov/>). The goal of this announcement is to develop advanced networking technologies that will enable the integration of ESnet and SDN capabilities into a unified backbone network infrastructure optimized for end-to-end high-throughput and operating in dual networking mode, offering best-efforts IP services and on-demand circuit services. In addition, DOE operates high-performance LANs in national laboratories to provide scientists with access to ESnet and SDN. These state-of-the-art networking facilities, along with the recently deployed nation-wide network demonstration prototype based on the emerging 100 GigE links technologies, provide a rich environment for researchers to develop and test new networking concepts. Potential applicants are encouraged to leverage the capabilities of networking resources in ESnet and national laboratories in developing and executing their proposed research.

Reference information:

- a) Workshop on Advanced Networking for Distributed Petascale Science: R&D Challenges and Opportunities. April 8-9, 2008. [Report in PDF](#)
- b) Workshop on Science-Driven R&D Requirements for ESnet, April 23-24, 2007. [Report in PDF](#)
- c) DOE's Next-Generation Networking for Science can found at this Website: <http://www.sc.doe.gov/ascr/Research/NextGen.html>.

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. 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>. Additional information on developing and submitting collaborative grant applications can be found:

<http://micsappl.ascr.doe.gov/ascr/Research/NextGen/collaboration.html>

PROGRAM FUNDING:

It is anticipated that up to \$3,500,000 total will be available for awards which are expected to be at most \$750,000 per year for multi-institution applications and \$175,000 per year for single investigator proposals. The funding period for all projects will be three years, subject to availability of funds. It is anticipated that up to three multi-institution and eight single awards will be made for this announcement contingent on availability of appropriated funds in **Fiscal Year 2010**.

DOE is under no obligation to pay for any costs associated with preparation or submission of pre- applications and applications. DOE reserves the right to fund, in whole or in part, any, all, or none of the applications submitted in response to this Announcement.

SUBMISSION INFORMATION:

The research project description must be 20 pages or less, exclusive of attachments and the required one-page abstract (see below). All collaborators should be listed with the abstract or summary. Attachments include curriculum vitae, a listing of all current and pending federal support and letters of intent when collaborations are part of the proposed research. Curriculum vitae should be limited to no more than two pages per individual.

The following is a list of essential items that a proposal must contain:

- 1. Field Work Proposal (FWP) Format** - Complete and signed by appropriate officials.
- 2. Proposal Cover Page**
- 3. Table of Contents**
- 4. Budget Page(s)** (Form DOE F 4620.1) - Complete a separate Budget Page for the entire multi- year period for each separate participating institution, if applicable.
<http://www.science.doe.gov/grants/budgetform.pdf>
- 5. Budget Description and Justification** - Separately for each collaborating institution if applicable.
- 6. Other Project Information**
 - a. A one-page abstract** (on a page by itself): The abstract must include, at the top of the page: the (lead) DOE National Laboratory, title of the project, name of the principal investigator (PI), the PI's telephone number and e-mail address, and a list of all collaborating investigators (if any) and their institutions. The abstract

must provide a summary of the project narrative, including the technical qualifications of the principal investigator.

b. Project Narrative (20 pages maximum): The project narrative must include a detailed description of the proposed research project, which must include a list of project milestones, a timeline of key activities, and clear statements of which project personnel will be responsible for each key activity.

c. Bibliography: A complete bibliographic listing of all the published scientific and engineering literature referred to in the project narrative.

d. Biographical Sketches: Relevant information about the background and experience of the principal investigator and co-principal investigators or collaborators (if any). Biographical sketches are limited to two pages per individual.

e. Facilities and Resources: Include information on the experience of the proposing institution(s), their facilities, and the available resources that would be relevant to successful completion of the project.

f. Statement of all current and pending support for the principal investigator and co- principal investigators and collaborators (if any), including the time devoted (each year) to each project by each named individual.

The instructions and format described below must be followed. You must reference Program Announcement LAB 10-264 on all submissions and inquiries about this Program Announcement.

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

After an initial screening for eligibility and responsiveness to this Announcement, proposals will be subjected to a formal scientific merit review (peer review). The proposals 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 Researcher's Personnel and Adequacy of Proposed Resources; and
- 4) Reasonableness and Appropriateness of the Proposed Budget.

The evaluation process will include program policy factors such as the relevance of the proposed research to the terms of the Announcement and the agencies' programmatic needs. Note that external peer reviewers are selected with regard to both their scientific expertise and the absence of conflict-of-interest issues. Both Federal and non-Federal reviewers may be used, and submission of a proposal constitutes agreement that this is acceptable to the investigator(s) and the submitting institution.

2. Summary of Proposal Contents

- Field Work Proposal (FWP) Format (Reference DOE Order 412.1A) (DOE ONLY)
- Proposal Cover Page
- Table of Contents
- Budget (DOE Form 4620.1) and Budget Explanation
- Abstract (one page)
- Narrative (main technical portion of the proposal, including background/introduction, proposed research and methods, timetable of activities, and responsibilities of key project personnel - 20-page limit)
- Literature Cited
- Biographical Sketch(es)
- Description of Facilities and Resources
- Other Support of Investigator(s)
- Appendix (optional)

2.1 Submission Instructions

Have your LAB administrator submit the entire LAB proposal and FWP via Searchable FWP (<https://www.osti.gov/fwp>). If you have questions about who your LAB administrator is or how to use Searchable FWP, please contact the Searchable FWP Support Center.

Please submit, via Federal Express, a single PDF file of the entire LAB proposal and FWP on a CD along with two hard copies to the address below. This will assist in expediting the review process.

Please send the CD and 2 hard copies via Federal Express to:

Teresa Beachley
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19901 Germantown Road
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ATTN: Program Announcement LAB 10-255

FOR FURTHER INFORMATION CONTACT:

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B) Deeply Integrated Middleware Services

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Richard Carlson, Program Manager
U. S. Department of Energy
Office of Advanced Scientific Computing Research
Phone: 301-903-9486
E-Mail: network_research@ascr.doe.gov

3.1 Field Work Proposal Format (Reference DOE Order 412.1A) (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.

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 Budget and Budget Explanation

A detailed budget is required for the entire project period 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.science.doe.gov/grants/budgetform.pdf>

3.5 Abstract

Summarize the proposal in one page. Give the project objectives (in broad scientific terms), the approach to be used, and what the research is intended to accomplish. State the hypotheses to be tested (if any). At the top of the abstract give the lead DOE national Laboratory, project title,

names of all the investigators and their institutions, and contact information for the principal investigator, including e-mail address.

3.6 Narrative (main technical portion of the proposal, including background/introduction, proposed research and methods, timetable of activities, and responsibilities of key project personnel).

The narrative comprises the research plan for the project and is limited to **20 pages (maximum)**. It should contain enough background material in the Introduction, including review of the relevant literature, to demonstrate sufficient knowledge of the state of the science. The major part of the narrative should be devoted to a description and justification of the proposed project, including details of the methods to be used. It should also include a timeline for the major activities of the proposed project, and should indicate which project personnel will be responsible for which activities. It is important that the 20-page technical information section provide a complete description of the proposed work, because reviewers are not obliged to read the Appendices. Proposals exceeding these page limits may be rejected without review or the first 20 pages may be reviewed without regard to the remainder.

All proposals submitted in response to this LAB Announcement must explicitly state how the proposed project will support the accomplishment of the program goals and the ASCR mission, including the project's impact on applications of interest to the Office of Science.

If any portion of the project is to be done in **collaboration** with another institution (or institutions), provide information on the institution(s) and what part of the project it will carry out. 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."

3.7 Literature Cited

Give full bibliographic entries for each publication cited in the narrative. Each reference must include the names of all authors (in the same sequence in which they appear in the publication), the article and journal title, book title, volume number, page numbers, and year of publication. Include only bibliographic citations. Principal investigators should be especially careful to follow scholarly practices in providing citations for source materials relied upon when preparing any section of the proposal.

3.8 Biographical Sketches

This information is required for senior personnel at the institution submitting the proposal and at all subcontracting institutions (if any). The biographical sketch is limited to a maximum of two pages for each investigator and must include:

Education and Training. Undergraduate, graduate and postdoctoral training, provide institution, major/area, degree and year.

Research and Professional Experience. Beginning with the current position list, in chronological order, professional/academic positions with a brief description.

Publications. Provide a list of up to 10 publications most closely related to the proposed project. For each publication, identify the names of all authors (in the same sequence in which they appear in the publication), the article title, book or journal title, volume number, page numbers, year of publication, and website address if available electronically. Patents, copyrights and software systems developed may be provided in addition to or substituted for publications.

Synergistic Activities. List no more than five professional and scholarly activities related to the effort proposed.

To assist in the identification of potential conflicts of interest or bias in the selection of reviewers, the following information must also be provided in each biographical sketch.

Collaborators and Co-editors: A list of all persons in alphabetical order (including their current organizational affiliations) who are currently, or who have been, collaborators or co-authors with the investigator on a research project, book or book article, report, abstract, or paper during the 48 months preceding the submission of the proposal. Also, include those individuals who are currently or have been co-editors of a special issue of a journal, compendium, or conference proceedings during the 24 months preceding the submission of the proposal. Finally, list any individuals who are not listed in the previous categories with whom you are discussing future collaborations. If there are no collaborators or co-editors to report, this should be so indicated.

Graduate and Postdoctoral Advisors and Advisees: A list of the names of the individual's own graduate advisor(s) and principal postdoctoral sponsor(s), and their current organizational affiliations. A list of the names of the individual's graduate students and postdoctoral associates during the past five years, and their current organizational affiliations.

3.9 Description of Facilities and Resources

Facilities to be used for the conduct of the proposed research should be briefly described. Indicate the pertinent capabilities of the institution, 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).

3.10 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 (months per year or percentage of the year) devoted to the project.

3.11 Appendix

Information not easily accessible to a reviewer may be included in an appendix, but **do not use the appendix to circumvent the page limitations of the proposal**. Reviewers are not required to consider information in an appendix, and reviewers may not have time to read extensive appendix materials with the same care they would use with 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 \$50,000 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.