Program Announcement
To DOE National Laboratories

LAB 12-742

Office of Science

Office of Advanced Scientific Computing Research (ASCR)

Resilient Extreme-Scale Solvers ("RX-Solvers")

GENERAL INQUIRIES ABOUT THIS LAB ANNOUNCEMENT SHOULD BE DIRECTED TO:

Technical/Scientific Program Contacts:

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http://science.energy.gov/ascr/funding-opportunities/

SUMMARY:

Advanced Scientific Computing Research (ASCR), Office of Science (SC), US Department of Energy (DOE), invites proposals for basic research in Resilient Extreme-Scale Solvers ("RX-Solvers") that demonstrably advances the state of science and practice for scalable, resilient, extreme-scale numerical algorithms, to enable scientific discovery on the supercomputers expected to come online in the next 5-10 years and lay the foundation for research in numerical algorithms for extreme-scale scientific computing.

The advancement of computer architectures is undergoing fundamental changes. Microprocessor clock speed has now reached an upper bound dictated by prevailing technology, thus improvement in performance of computers is now achieved by adding more processors to a chip. At the same time, power considerations are reducing the amount of memory available to each processor, and I/O bandwidth is not expected to keep up with performance growth. For the exascale machine, the power consumption needs to be an order of magnitude less than that extrapolated from today's energy consumption levels; the system memory is expected to be a fraction of the traditional ratio of 1 byte per floating-point operation per second (FLOPS); and the level of total concurrency is expected to be billions, if not tens of billions.

Today, at 1-10 peta-FLOPS (PF), evolutionary approaches, or "patches," to current programming and execution models (such as "MPI+X") are often employed to keep existing science application codes running, while leaving the underpinning numerical algorithms largely intact. This is akin to adjusting the exterior of an automobile to gain some fuel efficiency through aerodynamics without reexamining the internal combustion engine. For the extreme-scale computers – specifically, systems over 100 PF, that are expected to come online in the next 5-10 years -- the patch approach is not expected to be sustainable: even today, high-performance computational scientists have to manage data movement and communication explicitly for many existing architectures to achieve performance gains, and an increased number of soft errors and other faults have been observed or encountered. Independent of exact architectural detail of the next-generation supercomputer systems, serious refactoring or rethinking of today's numerical algorithms will be required.

We seek basic research in the design, synthesis, analysis, implementation, and demonstration of resilient numerical algorithms that are at the heart of DOE high-performance computing science and engineering applications, so that these applications will fully realize the promises of the next-generation extreme-scale supercomputers. These algorithms must address resilience or fault tolerance at an algorithmic level. The research team is expected to demonstrate the level of performance of the proposed algorithms through a combination of numerical analysis and numerical experiments, based on a suite of relevant, nontrivial performance metrics identified and specified by the research team itself.

More specific information is included under SUPPLEMENTARY INFORMATION below.

A companion Funding Opportunity Announcement (FOA) DE-FOA-0000742 will also be posted at http://www.grants.gov/ and on the SC Grants and Contracts web site at: http://www.science.doe.gov/grants.

PROPOSAL DUE DATE: August 13, 2012

Formal proposals submitted in response to this Program Announcement must be submitted from the Laboratory to the site office through Searchable FWP by **August 13, 2012, 11:59 p.m. Eastern Time**, to be accepted for merit review and to permit timely consideration for award in Fiscal Year 2013. **Each proposal should be in a single PDF file. The first few pages of the PDF should be the Field Work Proposal followed in the same PDF by the full technical proposal. You are encouraged to transmit your proposal well before the deadline. PROPOSALS RECEIVED AFTER THE DEADLINE WILL NOT BE REVIEWED OR CONSIDERED FOR AWARD.**

SUBMISSION INSTRUCTIONS:

LAB administrators should submit the entire LAB proposal and Field Work Proposal (FWP) via searchable FWP (https://www.osti.gov/fwp). Questions regarding the appropriate LAB administrator or other questions regarding submission procedures can be addressed to the Searchable FWP Support Center. All submission and inquiries about this Program Announcement must reference Program Announcement LAB 12-742

SUPPLEMENTARY INFORMATION:

The advancement of computer architectures is undergoing fundamental changes. These changes are expected to be disruptive, especially with regard to conventional wisdoms accumulated in the last 20-30 years of high-performance scientific computing.

Today, top supercomputers are capable of performing at around 1-3 PF. They consume 2-7 MW/year (at a cost of roughly $1M per MW per year). These systems may have around 20,000 processors, with a total concurrency of up to around 250,000. These systems may have a few hundred tera-bytes (TB) of total memory, 10's of peta-bytes (PB) of storage, and I/O bandwidth around a few hundred giga-bytes per second (GB/s).

An exascale system would be capable of performing 10^18 operations per second, one thousand times of the peta-scale machines. A 2008 DARPA study has determined that it is impossible to "scale" today's machine up to 1 EF; the power required to operate such a computer is the biggest obstacle. If one limits the power to about 20 MW, the exascale machine would still have O(100,000) – O(1,000,000) processors, with 10's – 100's of billions of total concurrency. The system memory is expected to be about 60 PB, with 500-1000 PB of storage. The I/O bandwidth may be around 60 TB/s.

In the next few years, before the exascale system would be designed, one may expect a few intermediate systems capable of performing at few hundred petaflops coming online. These intermediate systems will also not be scaled from today's 1-10 PF systems. Power consumption is expected to be an issue; by employing heterogeneous architectures, however, it may be feasible to build 100-300 PF systems that consume ~15 MW/year. In addition to heterogeneity, these systems also have a formidable level of concurrency: they may have 50,000 – 500,000 processors, with 10's – 100's of millions of total concurrency – at least 2-3 orders of magnitude of today's level of concurrency. The system memory may be around 5 PB -- continuing the trend of decreasing byte-per-flops, with a complex memory hierarchy. The storage may be around 150 PB, and the I/O bandwidth around 10 TB/s. Thus, even though not at exaflops, these intermediate machines embody the significant hurdles for the deployment of application codes – and for scientific discovery through simulation -- as we march towards exascale.

For a transition of DOE applications from today's 1-10 PF Leadership-class machines to the machines of the next 5-10 years, expected to be 100 PF or more, the main algorithmic challenges are

- Extreme concurrency: estimates of two to three orders-of-magnitude of parallelism over today's levels will require solvers to pay particular attention to Amdahl's Law;
- Complex memory hierarchies: algorithms that assume rapid access to large memory may end up having to access data from far away via (generally slower) interconnects; algorithms that wish to utilize local memory (such as cache or scratchpad) may face added complexities;
- Costly data movement: the energy required for communication is far greater than that required for floating point operations; optimizing the movement of data in algorithms may potentially reduce the power requirement;
- Nondeterministic behavior in hardware: due to manufacturing challenges and the high level of concurrency, the numbers of failures, soft-errors, and other faults are expected to increase to levels that cannot be ignored.

These challenges are not completely independent. As microprocessor clock speed reaches a plateau, increased concurrency becomes the predominant mechanism to increase performance. Technologies for memory systems have unfortunately not progressed as quickly as microprocessor; increasing the complexity of memory hierarchy can be viewed a compromise between the need to pack in more memory and the need to control the cost of the overall high-performance computing system. The current implementations of many applications, however, assume the availability of memory somewhere, thus further increasing communication and data movement – and increasing the energy consumption in the process. The unrealistic level of projected energy consumption is in turn driving hardware vendors to reduce or manage power consumption at a low level. With increased density and complexity of components operating near the limit of current technology, we expect to observe in future hardware "nondeterministic" behavior that may be attributed to increased stress and damage to system components and that are realized as faults, failures, and other errors.

Arguably, extreme concurrency, complex memory hierarchies, and costly data movement are challenges that may be overcome with technology (that is, with sufficient investment, sophistication, and advancement in hardware technology). Nondeterministic behavior in hardware, however, has its root cause in the laws of physics and will be far more difficult, even infeasible, to mitigate by technological advances alone. All these challenges are expected to persist for exascale systems and beyond.

Application performance on supercomputers has traditionally been measured by maximizing the number of FLOPS, often at the expense of data placement, storage, and movement. Numerical algorithms that are at the heart of high-performance scientific applications have counted on having sufficient – or sufficiently rapid access to -- memory, where necessary data, frequently multiple copies of data, would be stored. The impending architectural changes, brought on by increased level of concurrency and reduced memory, have significantly lowered the relative cost of floating point operations to data movement: once high-performing algorithms will become communication-bound and memory-bound, or slow and expensive.

The architectural changes also introduce significant uncertainty in the faults application codes running on these architectures will need to deal with. Historically, errors and faults are infrequent and would be handled at a low level (for example, by the microprocessors, by error-correction codes); the only higher-level option for dealing with unexpected failures is check-pointing, or writing large "restart" files frequently so that, if failure is encountered, one may return to a nearby "checkpoint" and use the information stored in the restart file to restart a run. With the exponentially increasing number of processors and with the I/O and memory bandwidths not improving at the same rate, applications are expected to be subject to a large number of hard (failure of a device) interrupts and soft (change of a data value) errors, and it may no longer be possible to write, store, and subsequently read restart files to counter the frequency with which faults are expected to occur. Numerical algorithms may no longer be able to rely on hardware or system software alone for resilience.

For the purpose of this Program Announcement, a "solver" is a numerical algorithm that provides a numerical solution to a mathematical model of a physical system of interest and of relevance to the Department of Energy missions. Examples of solvers include linear algebra algorithms such as direct and iterative linear solvers, nonlinear solvers, and eigensolvers, for large systems; numerical methods for solving composite systems of partial differential equations; algorithms in optimization or mathematical programming; etc. Low-level, fundamental routines such as basic arithmetic operations or Fast Fourier Transform (FFT) will not be considered as a suitable “solver” for the purpose of this Program Announcement.

To be considered for recommendation for awards, applications to this Program Announcement must include three elements:

1. Advances in solvers: For solvers to meet the architectural challenges of the extreme-scale machine 100 PF and beyond, they need to achieve optimal data movement and maximize available memory and I/O bandwidths. For example, strategies for achieving optimal data movement may include utilizing variable-precision arithmetic, reordering algorithms to “trade computation for communication”, explicitly exploiting the machine’s memory hierarchies, etc.; strategies for maximizing available bandwidths may include reducing global synchronization, “bringing computation to the data” by including more auxiliary calculations such as in situ data analysis and uncertainty quantification, designing and employing latency-tolerant algorithms such as parallel time integration, etc. Advances in solvers may be achieved by, for example, revisiting past algorithms, refactoring current, existing algorithms, or rethinking the mathematics for new classes of algorithms.

2. Fault tolerance and resilience at the algorithmic level: Future architectural challenges bring the issue of resilience to front and center. The number of faults, whether detected or corrected or not, is expected to increase with increasing system size and complexity. Traditional approaches to resilience and fault tolerance, such as assuming low-level error correction, redundancy, and checkpoint-restart, are not expected to be adequate, affordable, or possible. Algorithmic research for high-performance computers should include resilience and fault tolerance as a value-added feature of the numerical algorithm, a feature that can be “turned on” when deploying the algorithm on a new, experimental, or developmental architecture or “turned off” as the reliability of a computing system becomes predictable. . Resilience presents a rare opportunity for revolutionary innovations in algorithmic research. For resilience at the algorithmic level, solvers may consider embracing non-determinism, by, for example, employing stochastic or probabilistic methods to minimize the overall effects of faults. Solvers will need to detect, run through, or otherwise recover from various sources of faults – indeed, even defining what we mean by “correct” or “reproducible” may require research.

3. Performance of proposed algorithms: A particular difficulty in solvers research is the demonstration of the performance predictions of any new algorithm. Architecture simulators are usually not available to or easily accessible by designers of numerical algorithms, who are typically applied mathematicians and numerical analysts, as are appropriate abstract machine models, performance simulation tools, and (preferably – architecture-independent) programming models. Performance measurement tools are needed in order to guide the implementation of algorithms; these tools should measure all aspects of performance, including execution time, memory performance, data movement, faults, and energy consumption. For the extreme-scale systems, many of these models and tools are current research topics in computer science. Without the means of measuring, characterizing, validating, or otherwise quantifying the performance predictions of the new algorithms on upcoming architectures, solvers designers alone may find it difficult to gauge progress. Researchers in numerical algorithms are

encouraged to perform traditional numerical analysis and, in collaboration with other experts, leverage and explore tools and models that will help them characterize new algorithms beyond using the traditional flop count, propose performance metrics that more closely represent the realities of scientific computing in the extreme-scale era. Researchers are expected to devise a suitable suite of performance metrics and demonstrate, beyond “toy problems”, “linearized analysis”, or “back-of-the-envelope estimates”, measurable progress towards conquering the extreme-scale challenges.

Preference will be given to integrated algorithmic research projects (“large teams”) that consider a broad spectrum of the challenges to solvers holistically; however, a small number of smaller projects (“small teams”) that propose technically sound and imaginative research for specific challenges in solvers may be considered. Please see Award Information (Part II) below for detail. All projects will be subject to the same Merit Review criteria. Please see Application Review Information (Part V) below for the Merit Review criteria.

No architectural or hardware research will be considered for funding, either as a part of a collaboration or as a stand-alone project. Requests may not include funds for hardware lease or purchase.

Applications whose research plans do not include numerical algorithms research in a substantive manner will be deemed nonresponsive. Applications whose research plans do not include work in resilience or fault tolerance in a substantive manner will be deemed nonresponsive. Applications whose research plans do not include characterization and demonstration of the performance of proposed algorithms in a substantive manner will be deemed nonresponsive.

Each project is expected to have a management plan appropriate for the size and complexity of the project. The roles of senior and key personnel must be clearly articulated. A communication plan, both for communication within the project and for communication with the broader community, is expected from each project. The Principle Investigator is expected to commit sufficient time to be accountable for the successful execution of the project’s plans. Other senior project personnel are expected to commit sufficient time in order to make significant technical contributions to the project. The project’s management and communication plans and the levels of commitment of effort of lead project investigator, key personnel, and other senior personnel will be considered in Merit Review.

References

“Scientific Grand Challenges: Crosscutting Technologies for Computing at the Exascale”, report from the workshop held February 2-4, 2010.
http://science.energy.gov/~/media/ascr/pdf/program-documents/docs/Crosscutting_grand_challenges.pdf

“The Opportunity and Challenges of Exascale Computing”, summary report of the Advanced Scientific Computing Advisory Committee (ASCAC) Subcommittee. Fall 2010.
http://science.energy.gov/~/media/ascr/ascac/pdf/reports/Exascale_subcommittee_report.pdf

Kogge, Peter, “Next-Generation Supercomputers”, IEEE Spectrum, February 2011. http://spectrum.ieee.org/computing/hardware/nextgeneration-supercomputers/0
“Exascale Programming Challenges”, report from the Workshop on Exascale Programming Challenges held July 27-29, 2011.
http://science.energy.gov/~/media/ascr/pdf/program-documents/docs/ProgrammingChallengesWorkshopReport.pdf

“Tools for Exascale Computing: Challenges and Strategies”, report from the Exascale Tools Workshop held October 13-14, 2011.
http://science.energy.gov/~/media/ascr/pdf/research/cs/Exascale%20Workshop/Exascale_Tools_Workshop_Report.pdf

“Workshop on Extreme-Scale Solvers: Transition to Future Architectures”, report from the Extreme-Scale Solvers Workshop held March 8-9, 2012.
http://science.energy.gov/~/media/ascr/pdf/program-documents/docs/reportExtremeScaleSolvers2012.pdf

Collaborations: Collaborative research projects with other institutions, such as universities, industry, non- profit organizations, and Federally Funded Research and Development Centers (FFRDCs), including the DOE National Laboratories, are strongly encouraged. Collaborative proposals submitted from different institutions should clearly indicate they are part of a proposed collaboration and contain the same title, Abstract and Narrative for that research project. In addition, such proposals must describe the work and the associated budget for the research effort being performed under the leadership of the Principal Investigator at that participating institution. These collaborative proposals should all have the same title as the Lead Institution.

Program Funding: Awards are expected to be made for a period of three years at a funding level of up to $4,500,000 per year to support multiple awards in Fiscal Year 2013, with out-year support contingent on the availability of appropriated funds and satisfactory progress.

The awards will be made in the following two categories:

- Large team awards: awards involving multiple investigators from two or more institutions. The funding level for these awards will be roughly around $1M -- $2.5M per year for up to three years.
- Small team awards: awards involving single investigators or small teams. The funding level for these awards will be up to $250K per year for up to three years.

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

The instructions and format described below should be followed. You must reference Program Announcement LAB 12-742 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 DOE 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:

Initial Review Criteria

Proposals will be subjected to scientific merit review (peer review) and will be evaluated against the following evaluation criteria which are listed in descending order of importance. Included within each criterion are specific questions that the merit reviewers will be asked to consider:

1) Scientific and/or technical merit of the project

- Does the proposed research significantly advance the state-of-the-art in numerical algorithms for scientific discovery, and will meet the architectural challenges of extreme-scale systems?
- Does the proposed research clearly address fault tolerance and resilience at an algorithmic level?
- Does the research plan contain scientifically valid performance metrics that will allow progress to be measured?
- Does the proposed research have the potential to have significant, far-reaching impact beyond the next-generation extreme-scale computers?

2) Appropriateness of the proposed method or approach

- How feasible is the proposed research plan for the advancement of numerical algorithms for scientific discovery?
- How feasible is the proposed research plan to address fault tolerance and resilience at an algorithmic level?
- How feasible is the proposed plan for the characterization and demonstration of the performance of proposed algorithms?
- What is the likelihood that the applicant can overcome the key challenges and, as warranted, shift research directions in response to promising advances in basic research?

3) Competency of the applicant's personnel and adequacy of the proposed resources

- Has the applicant requested sufficient time and resources to execute the research plan successfully?
- Does the project have a sound communication plan?
- Does the project have an appropriate and effective management plan?

- Is the Principle Investigator capable of leading this project and being accountable for the successful execution of the project’s technical, management, and communication plans?
- Are the roles of senior or key personnel clearly and adequately described, and have these senior or key personnel committed sufficient level of effort to ensure the success of this project?

4) Reasonableness and appropriateness of the proposed budget

- Is the requested manpower reasonable and appropriate?
- Is the travel budget appropriate?

The selection official will also consider the following program policy and management factors:

- Relevance of proposed research to DOE missions;
- Potential impact of proposed research activities on ASCR Exascale goals and objectives;
- Potential for developing synergies and/or relation of the proposed research activities to other research efforts supported by ASCR, such as those in applied mathematics and computer science; and
- Total amount of DOE funds available.

The evaluation process will include program policy factors such as the relevance of the proposed research to the terms of the Program Announcement and the agency's 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 – 15-page limit
- Literature Cited
- Biographical Sketch(es)
- Description of Facilities and Resources
- Other Support of Investigator(s)
- Appendix (optional)

2.1 Submission Instructions

LAB administrators should submit the entire LAB proposal and Field Work Proposal (FWP) via searchable FWP (https://www.osti.gov/fwp). Questions regarding the appropriate LAB administrator or other questions regarding submission procedures can be addressed to the Searchable FWP Support Center. All submission and inquiries about this Program Announcement must reference Program Announcement to DOE National Laboratories LAB 12-742. Full proposals submitted in response to this Program Announcement must be submitted to the searchable FWP database no later than 11:59 pm, Eastern Time, **August 13, 2012**. It is important that the entire peer reviewable proposal be submitted to the searchable FWP system as a single PDF file attachment.

3. Detailed Contents of the Proposal

Adherence to type size and line spacing requirements is necessary for several reasons. No researcher should have the advantage, or by using small type, of providing more text in his or her proposal. Small type may also make it difficult for reviewers to read the proposal. Proposals must have 1-inch margins at the top, bottom, and on each side. Type sizes must be at least 11 point. Line spacing is at the discretion of the researcher but there must be no more than 6 lines per vertical inch of text. Pages should be standard 8 1/2" x 11" (or metric A4, i.e., 210 mm x 297 mm).

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 and number: **Resilient Extreme-Scale Solvers ("RX-Solvers") - LAB 12-742**
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:

Is this a Collaboration? If yes, please list ALL Collaborating Institutions/PIs and indicate which ones will also be submitting applications. Also indicate the PI who will be the point of contact and coordinator for the combined research activity.

The Lead-PI should include the following table on the cover page.

Sample Table for the Lead Institution ($ in thousands)

	Year 1	**Year 2**	**Year 3**	**Total**
Name of PI and Institution	$	$	$	$
Name of Co-PI and Institution	$	$	$	$
Name of Co-PI and Institution	$	$	$	$
Name of Co-PI and Institution	$	$	$	$
Total	$	$	$	$

Note that collaborating proposals must be submitted separately.

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/BudgetForm4620.pdf

3.5 Abstract

Summarize the proposed work 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 a **maximum of 15 pages** when printed using standard 8.5” by 11” paper with 1 inch margins (top, bottom, left, and right) with font-size no smaller than 11 points. 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.

The page count of 15 does not include the Cover Page and Budget Pages, the Title Page, the biographical material and publication information, or any Appendices. However, it is important that the 15-page technical information section provide a complete description of the proposed work, since reviewers are not obliged to read the Appendices. Please do not submit general letters of support as these are not used in making funding decisions and can interfere with the selection of peer reviewers.

Background

Background – explanation of the importance and relevance of the proposed work.

Proposed Research and Tasks

In addition to the technical description of the proposed work and tasks, include a discussion of schedule, milestones, and deliverables.

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. For publications or collaborations with more than 10 authors or participants, only list those individuals in the core group with whom the Principal Investigator interacted on a regular basis while the research was being done. 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. If letters of endorsement are included in a proposal, they will be removed before the proposal is submitted for review.

4. Detailed Instructions for the Budget (DOE Form 4620.1 "Budget Page" is preferred and is located at: http://www.science.doe.gov/grants/BudgetForm4620.pdf

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.