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SENT VIA EMAIL ON July 12, 2011

July 12, 2011

TO ALL PROSPECTIVE RESPONDENTS:

Subject: ***Request For Information (RFI) No. 1-KD73-I-31583-00***

UChicago Argonne, LLC, operator of Argonne National Laboratory (Argonne), under a prime contract with the U.S. Department of Energy (DOE), along with six other DOE laboratories: Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Sandia National Laboratories, and Pacific Northwest National Laboratory and Pacific Northwest National Laboratory have formed a consortium (referred to as E7) to manage the Request for Information (RFI) process to deliver platform and crosscutting co-design and critical research and development (R&D) technologies targeted at deploying exascale computers by 2019-2020. The E7 is performing a market survey to evaluate obtaining products and services that are the subject of this RFI. Therefore, you are invited to submit a response to this RFI to provide the supplies and services outlined below. This RFI is for informational purposes only and will not necessarily result in a solicitation or award of a contract.

PROJECT: EXASCALE RESEARCH AND DEVELOPMENT

The purpose of this request for information (RFI) is to provide the DOE Office of Science and the DOE National Nuclear Security Administration Office of Defense Programs with information for responding to a request from the House Energy and Water Development subcommittee of the House Appropriations Committee and for planning the DOE exascale program as more fully described in Attachment 1 titled, "Exascale Research and Development," dated July 8, 2011. Your written response should include written materials describing your R&D plan, the resources required, the cost range, major milestones, the timeline, and any other relevant information you deem appropriate to address your ability to provide technology advances, designs, prototypes, and testbeds relevant to development of the exaflops computing system.

Additionally, responses may include proprietary information. Respondents should indicate on the fore page, and all subsequent pages of their response to this RFI, those sections, paragraphs, or areas which they consider to be proprietary or otherwise considered confidential. Argonne, the

other members of E7, and DOE assume no liability for disclosure or use of unmarked data, and may use or disclose such data for any purpose. Unless restricted, information submitted in response to this RFI and subsequently used for procurement purposes may become subject to public disclosure pursuant to the provisions of the "Freedom of Information Act."

Responses are due no later than 4:00 PM CDT on or before September 2, 2011. Responses should not exceed 50 pages. Responses as well as questions about the RFI should be submitted electronically to Karl D. Duke at kduke@anl.gov.

A Pre-Response Telephone Conference will be held on July 28, 2011 at noon CDT. RFI questions for the phone conference must be submitted via e-mail on or before July 20, 2011 at 4:00pm CDT. Additional telephone conference information and answers to pertinent questions will be posted to the following web site: http://estrfi.cels.anl.gov. Answers to similar questions will be consolidated. It is your responsibility to check this page for new information.

Please Reference: RFI No. 1-KD73-I-31583-00 on all transmittals related to this RFI.

Please note that all responses to this RFI will be nonbinding. Also, this RFI does not commit Argonne to pay any cost for the preparation and submission of any information in response to this RFI.

Sincerely,

Karl D. Duke

Karl D. Duke
Contract Specialist, Senior
Procurement Department

KD/

Enclosures:

Attachment 1
Exascale Research and Development
Request for Information

July 8, 2011

Exascale Program

The U.S. Department of Energy (DOE) has a long history of deploying leading-edge computing capability for science and national security. The currently proposed Exascale Program is motivated by DOE's compelling science, energy assurance and national security needs that require—as quickly and energy-efficiently as possible—a thousand-fold increase in usable computing power. Those needs, and the ability of high-performance computing to address other critical problems of national interest, are described in reports from each of the ten DOE Scientific Grand Challenges Workshops that have convened since November 2008. Each workshop and its report focused on a particular area: climate, high energy physics, nuclear physics, fusion energy sciences, nuclear energy, basic energy sciences, biology, national security, architectures and technology, and cross-cutting topics.[1] A common finding across these efforts was that scientific simulation and data analysis requirements are exceeding petascale capabilities and rapidly approaching the need for exascale computing. In April 2011 a Memorandum of Understanding was signed between the Department of Energy Office of Science (SC) and the DOE National Nuclear Security Administration (NNSA) Office of Defense Programs regarding the coordination of exascale activities across the two organizations.

The purpose of this request for information (RFI) is to provide the DOE SC and the DOE NNSA Office of Defense Programs with information for responding to a request from the House Energy and Water Development subcommittee of the House Appropriations Committee and for planning the DOE activities leading to the development of production exascale platforms. Among these activities will be the formation of partnerships between laboratories and industry to perform platform and crosscutting co-design and critical technologies research and development (R&D) targeted at delivering exascale computers by 2019–2020. Figure 1 is a conceptual timeline that can serve as a guide to the timing constraints on your response.

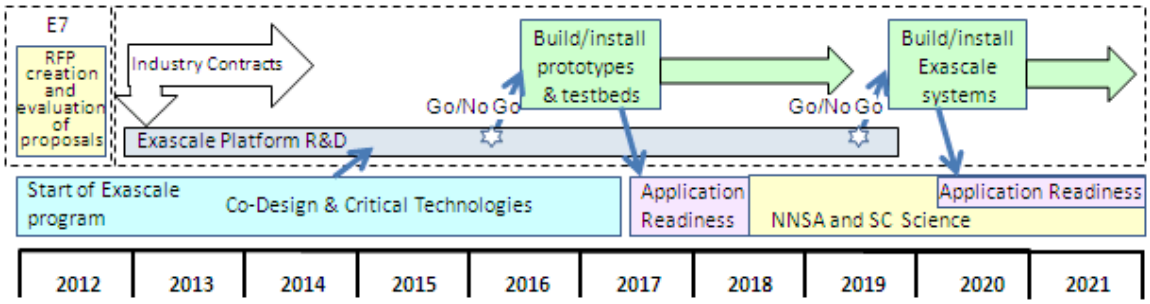

Figure 1. Conceptual exascale program roadmap. This is a conceptual diagram that may change as program and funding plans evolve.

Seven Laboratory Consortium

Seven DOE laboratories—Argonne, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest, and Sandia national laboratories—have formed a

[1] See http://extremecomputing.labworks.org/index.stm.

consortium (referred to as E7) to carry out the RFI to inform planning across the exascale activities as shown in Figure 2. For the past three decades these laboratories have acquired and run some of the most powerful computers in the world. They have the physical infrastructure, expertise, and experience in high-performance computing (HPC) that makes their participation critical to the success of the exascale activities. Their successes with laboratory-industry R&D collaborations have produced breakthrough computers for DOE missions.

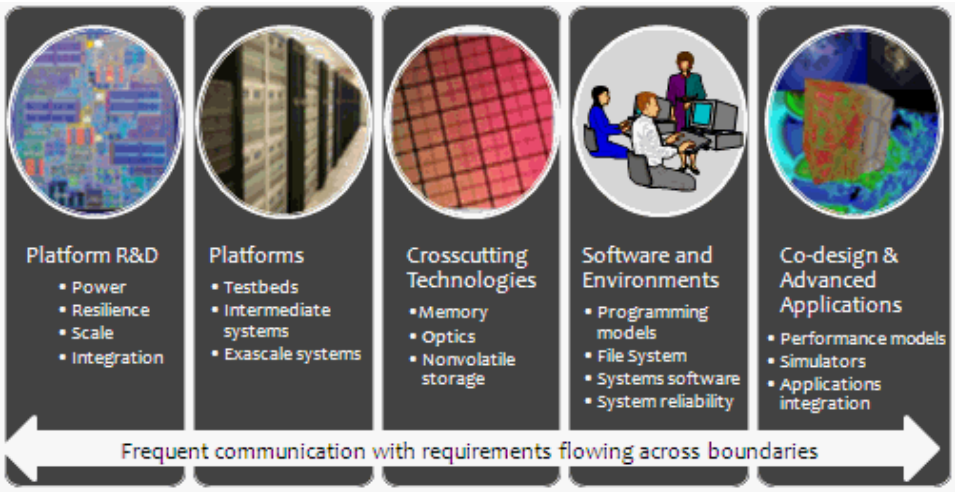

Figure 2. Communication and integration across the exascale activities is key to success.

Laboratory-Industry Team Partnerships

In a decade-long roadmap to reach exascale it is anticipated that the DOE national laboratories will form partnerships with industry teams for R&D targeted at delivery of exascale platforms to serve the needs of DOE SC and NNSA. Our expectation is that industry teams will assemble based on business interests. Each self-assembled industry team will have a single prime subcontractor for the duration of the R&D program, as shown in Figure 3. The laboratory partnership will be responsible for negotiating subcontracts with the prime subcontractor for both the required platform-specific R&D and (if the R&D is successful) the acquisition of exascale systems. For the R&D efforts, the tailored project management model will include risk management and progress payments against milestones. The laboratory partnership will be responsible for monitoring the progress toward scheduled milestones, overseeing risk management, and assisting the industry teams in their co-design efforts.

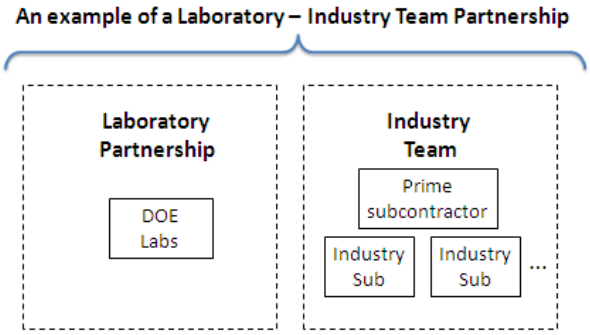

Figure 3. Industry teams led by a prime will form partnerships with DOE laboratories.

RFI Discussion

Co-design and R&D

The R&D that is the focus of this RFI is expected to be a co-design process. The DOE Office of Advanced Scientific Computing Research (in the Office of Science) and the NNSA Advanced Simulation and Computing Program (in the Office of Defense Programs) are establishing several co-design application centers[2] and software projects that will collaborate with companies on architectural choices for system designs developed under the envisioned R&D projects. Co-design feedback will have a pivotal role in prioritizing R&D investments. The level of co-design effort that will be required by the companies depends on the specific technology R&D being pursued and the project plans for the DOE co-design efforts. Note that here "technology" refers to either hardware or software, and both are candidates for co-design.

We anticipate that the R&D required on the path to exascale will require platform and crosscutting co-design and critical technologies research and development. R&D efforts may range from integrated efforts from industry teams to standalone efforts from individual companies.

Prototype and Testbed Systems

Prototypes of many kinds and scales play key roles in high-end computer R&D, from components with specific features to systems with extensive capabilities (perhaps at reduced scale). It is expected that the respondent's R&D plans will incorporate an appropriate set of prototype systems, including design validation and design analysis with both design teams and co-design partners.

It is anticipated that testbed and prototype systems will be needed in the process of getting from petascale to exascale. The purposes of these systems are twofold:

- Technology checkout
- Application readiness

Because the power, resilience, and performance targets of the exascale system are at least an order of magnitude better than what is projected to be available from commodity system roadmaps, new hardware architectures and technologies and new software techniques must be developed to meet these targets. Testbed systems provide both DOE and the industry team(s) a platform to evaluate the new technologies being developed for the exascale system and to refine designs. The testbed systems will also provide a system that application and systems software teams can use to change and test their codes for the exascale system(s). This activity will foster intense co-design as the productivity of the new technologies is evaluated and exascale designs are refined. The ultimate goal is the advancement of DOE missions and U.S. science.

Goal of This RFI

The primary goal of this RFI is to provide DOE with information for planning its exascale program. Specifically we seek to do the following:

- Identify technology areas requiring R&D co-investment by DOE to achieve its objective

[2] Background on DOE's plan for Exascale Co-design Centers can be found in the solicitation at http://science.energy.gov/~/media/ascr/pdf/funding/notices/Lab_10_07.pdf.

of acquiring exascale systems in 2019-2020 timeframe.

- Determine the necessary R&D and the level of R&D investment (scope, schedule and budget) required by DOE to secure the necessary exascale technology.
- Establish the level of interest, corporate capabilities, and anticipated roles of industry in working with DOE to achieve its goals for exascale computing.
- Understand the business challenges associated with working with DOE as part of a collaborative, multi-company exascale partnership (e.g., protection of intellectual property).

Exascale System Challenges

Significant technical challenges must be faced in meeting the needs of the computational science community over the next decade, among these are power, performance, concurrency, cost, and resiliency. The system goals are aggressive, and thus tradeoffs will be necessary. One tradeoff arena is between R&D and acquisition; for example, additional R&D might substantially reduce the cost of the system. Another tradeoff is among the various targets themselves; that is, reducing memory bandwidth would reduce system power but negatively affect application performance. Table 1 presents sample system goals for planning purposes.

Table 1. Exascale System Goals

Exascale System	Goal
Delivery Date	2019-2020
Performance	1000 PF LINPACK and 300 PF on to-be-specified applications
Power Consumption*	20 MW
MTBAI**	6 days
Memory including NVRAM	128 PB
Node Memory Bandwidth	4 TB/s
Node Interconnect Bandwidth	400 GB/s

*Power consumption includes only power to the compute system, not associated storage or cooling systems.
**The mean time to application failure requiring any user or administrator action must be greater than 24 hours, and the asymptotic target is improvement to 6 days over time. The system overhead to handle automatic fault recovery must not reduce application efficiency by more than half.
PF = petaflop/s, MW = megawatts, PB = petabytes, TB/s = terabytes per second, GB/s = gigabytes per second, NVRAM = non-volatile memory.

Several DOE reports[3] as well as the International Exascale Software Project (IESP) Roadmap[4] have identified emerging exascale system design characteristics, although they note that details will not become clear until the systems are actually developed.

Myriad challenges are associated with building systems having these design characteristics and capable of achieving the anticipated system targets. These challenges have been identified in

[3] http://science.energy.gov/ascr/news-and-resources/workshops-and-conferences/grand-challenges/

[4] The International Exascale Software Project Roadmap, http://www.exascale.org/mediawiki/images/2/20/IESP-roadmap.pdf

publications by DOE,[5] DARPA,[6] and others. Table 2 lists several of the technical challenges that the RFI responses may wish to address. Responses are not limited to this list.

Table 2: Architecture and Technology Challenges to Building Exascale Computers for DOE Missions

Category	Challenge
Fault Management and Resiliency	Improved RAS
	APIs for resilience (OS access to RAS)
	"Fault-oblivious" error-tolerant software
	Fault resilient algorithms and applications
	Fault-tolerant I/O
	Local recovery and migration
	Checkpoint-restart
	Component "sparing"
	Improved whole-system MTBAI (mean time between application interrupt, requiring user or administrator action)
Power Efficiency	Energy-efficient building blocks: CPU, memory, interconnect
	Novel cooling and packaging
	Whole-system power consumption
	Si-photonic communication
	Power-aware runtime software and algorithms
	Power performance-monitoring tools
Programming Models and Environments	Heterogeneous node programming model
	Extreme concurrency model
	Cross-platform programming models and runtime
	Correctness and performance tool scalability
	Fault-aware debugging
	Interoperability and composability
Scalability, Parallelism and Locality	Architecture-aware algorithm/libraries
	Scalable algorithms
	Micro- and macroarchitectures
	Collective OS operations
	Software-managed memory
	Communication avoidance algorithms
Memory and Storage	NVRAM "gap fillers"
	Photonic DRAM
	Alternative memory technologies
	Optical interconnects
	Proactive caching mechanisms
	Chip stacking
	Communications-optimized algorithms

[5] DOE Scientific Grand Challenges Workshop: "Architectures and Technology for Extreme Scale Computing," http://extremecomputing.labworks.org/hardware/report.stm

[6] ExaScale Computing Study: Technology Challenges in Achieving Exascale Systems, http://users.ece.gatech.edu/~mrichard/ExascaleComputingStudyReports/ECSS%20report%20101909.pdf

Not all challenges will be technical. Managing intellectual property will be an important part of the exascale program. An entity may wish to retain intellectual property rights to new intellectual property developed under R&D and critical technology subcontracts, provided that the appropriate cost-sharing conditions exist and documentation is filed supporting approval of a waiver by DOE. The retention of copyright by a subcontractor (large or small) for works of authorship is typically included in the DOE waiver. See DEAR 952.227-84 and 10 CFR Part 784 for additional information about how DOE can handle intellectual property ownership issues.

The body of existing DOE applications forms another set of exascale challenges. Supercomputing has enjoyed a stable programming paradigm for more than a decade, steadily enabling performance increases in scientific applications. Exascale platforms in the coming decade will provide a dramatic increase in computing power, with a rapid escalation in parallelism and advanced features incorporated into supercomputers. As applications seek to utilize these new features, the software transition will be at least as profound and challenging as the change from vector architectures to massively parallel computers that occurred in the early 1990s. A large investment in existing application codes complicates DOE's programming model needs. While we encourage innovative solutions that require writing applications, we also value models that exploit exascale hardware and accommodate code written by using existing techniques (e.g., MPI and OpenMP). Regardless of the approach, we value programming models that can provide interoperability and composability with existing codes.

Requested Information

DOE is collecting information in all the areas specified below, including your comments on the feasibility of the DOE goals in Table 1 and the opportunities and cost ranges to accelerate the schedule. Time is of the essence, so the response date will not be extended. Clearly mark every page that contains proprietary information as instructed in the RFI cover letter.

It is not necessary to respond to all questions. Further, if a topic that your company believes is important to the exascale program is not listed, include that in your response.

Questions have been structured, where possible, by the role your company intends to have in the exascale program. The E7 envisions three categories of responders to this RFI:

- Prime subcontractor, where the response is an integrated response from members of a company or self-assembled team of companies targeting integrated R&D for exascale systems (i.e., an exascale platform);
- Critical technology subcontractor, where the response is from a company or team of companies interested in developing critical technologies; or
- Potential team member to a prime or critical technology subcontractor, companies that would like to become associated with one of the previous two categories but have not joined a team yet.

How you envision your company's role should determine which questions will be germane to your response. The E7 recognizes that some companies have begun to collaborate on exascale technologies, and therefore a team response would be acceptable. In that case please identify all team members and their specific roles.

Attachment 1: Exascale Research and Development Request for Information

1. Corporate Capabilities

Questions for all respondents

1.1 Describe the contracting role you envision your company having in the exascale program (e.g., hardware or software technology provider, component provider, system design or engineering, system integrator, or prime subcontractor for a comprehensive system R&D effort), and describe the experience your company has in this role.

1.2 Provide examples of past, current, or future R&D efforts in your company's area of expertise, and explain how those efforts will enable you to address the challenges of exascale scientific and engineering computing.

1.3 Describe the organization within your company responsible for R&D and give an overview of its staffing and personnel skills, knowledge, and abilities. (Do not submit resumes of current employees at this time.)

1.4 Describe how high-performance computing fits into your corporate business strategy and product roadmaps.

2. Technical Aspects

Questions for all respondents

2.1 Identify and describe the specific hardware and software technology areas that you feel require additional R&D to meet DOE exascale requirements and that your company (and its subcontractors) would be interested in pursuing through an R&D partnership with the E7 labs or a subset thereof. Provide in your response the current state of the technology, including the current development path and schedule for the technology and the anticipated progress within the timeframe of the proposed work without additional federal investment. This area of the response gives the E7 a description of the "launching point" for the R&D. If the R&D were fully funded for the required timescale, what would be the resulting functionality and capability? Describe how this will impact the Exascale Program and the HPC community at large.

2.2 Describe the resources required and timeframe for the R&D efforts and the roadmap for associated testbeds and prototypes. How would the effort, if funded, achieve a systematic acceleration in the indicated technology area over that described in the "current status" above? Indicate major milestones in the project during the proposed lifetime of the project.

2.3 Provide a cost range for each R&D effort identified above either quarterly or yearly. Describe and estimate the co-investments (also called cost sharing) your company/team envisions making in those R&D efforts.

2.4 Describe how the timeline of your R&D efforts would mesh with the conceptual exascale platform timeline shown in Figure 1.

2.5 The Exascale Program is not directed at generating one-offs. That is, this process was initiated to accelerate the time to market for commercial products. We ask that you indicate how you might in the future commit to commercialization of the developed technology and the anticipated timeline for commercial product offerings. Indicate any barriers that your effort might have to making such productization commitments in the future.

Question for potential prime subcontractors

2.6 Identify critical technologies, in other words, needed cross-cutting R&D that would benefit all prime subcontractors.

Question for potential critical technology subcontractors

2.7 Describe how more than one platform developer could use your technology. Please describe your integration and testing strategy.

Question for potential team member to a Prime Subcontractor or Critical Technology Subcontractor team

2.8 Describe how you intend to develop a partnership with a platform or critical technology developer and your strategy for integrating your R&D efforts with those of your potential partner(s).

3. Collaboration Model

Questions for all respondents

3.1 Hardware-Software-Application co-design is a central element of DOE's Exascale Program. Describe your approach to working with DOE's co-design teams, for example, the exascale co-design centers (http://science.energy.gov/~/media/ascr/pdf/funding/notices/Lab_10_07.pdf) and other DOE-funded software and application R&D efforts.

3.2 Collaboration in advanced technology R&D typically involves access to significant intellectual property well in advance of its public release. What IP management approaches do you prefer for the subject R&D?

3.3 Identify any other IP concerns you might have, and propose a strategy for dealing with these concerns.

3.4 Describe opportunities for and expectations of collaboration with the DOE community.

Question for potential prime subcontractors

3.5 Provide a summary of proposed key collaborations and how your proposed R&D efforts will be managed and, in particular, how multiple organizations within your partnership will be coordinated.

4. Other Comments

Questions for all respondents

4.1 Make any other comments here, for example, concerning financial, technical, administrative, or contracting.