Exascale Co-design Consortium (ECDC): Operations Plan

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Exascale Co-design Vendor Engagement Model

Application-driven co-design is the process where scientific problem requirements influence computer architecture design, and technology constraints inform the formulation and design of algorithms and software. DOE exascale co-design efforts will involve the interaction of multiple application development teams, runtime infrastructure teams, programming models teams, and hardware design teams (in fact, the entire exascale ecosystem). It is impractical to support MxN interactions between M co-design centers and N vendor teams. Therefore, we are establishing a joint activity that spans the co-design centers – an Exascale Co-Design Consortium (ECDC) – to serve as the hub for our vendor and exascale ecosystem interactions.

Organization of these efforts will be a complex task and must be done in recognition of the limited number of meaningful interactions that any individual team can conduct with other co-design elements. Furthermore, it is of critical importance that vendors have confidence that proprietary information is protected and export control regulations are followed. The significant lead time we have until exascale architectures are deployed means that highly sensitive information could be shared under NDAs, and the vendors' confidentiality respected so they can maintain their competitive advantages. Through discussions with many vendors, three levels of interaction are expected: open, in which proxy apps are exchanged and an open analysis is used to answer open co-design questions (see below); generic NDA, in which long range plans are discussed and access is given to hardware; and deep NDA in which cycle accurate results are exchanged. It is expected that some technologies accelerated by the DOE exascale thrust will spread to other product lines, and the issue of information protection would have bearing even on mainstream product roadmaps.

Effective co-design must inject information where it can have impact, execute necessary follow-up, and record discussion and design decisions. While individual application and software co-design teams can and should have direct, sometimes confidential, contact with hardware vendors, our proposed ECDC will facilitate and coordinate co-design activities. The ECDC will be open to all co-design centers, including current and future ASCR and NNSA/ASC co-design centers. The ECDC will lead the collective effort to:

- Establish a point of entry, through which any vendor or any participant in the exascale thrust can participate in the application-driven co-design process.

- Establish a repository (web page), with links to all active co-design efforts and related mini-app development efforts, through which the exascale community can gain access to the application requirements and the continuously evolving proxy application codes.
- Directly engage each of the relevant exascale hardware and technology vendors to ensure clear communication and common understanding,
- Engage all of the supercomputer centers, in particular those owned and operated by DOE,
- Coordinate activities (e.g., programming model research) and share resources (e.g., simulators, performance analysis tools, staff expertise) between projects, and
- Assist in establishing and executing productive vehicles (e.g., open analysis results, workshops, on-site visits, secure on-line resources, etc.) for the rapid and multi-directional exchange of information within the exascale ecosystem.

The co-design centers will make extensive use of proxy applications to represent the application workflow and requirements to the exascale ecosystem. In general, a small application code that poxifies (stands for) some aspect of the computational workflow of a full application is a proxy app. Proxy apps can be grouped into categories in increasing sophistication and fidelity to the parent applications:

- Kernels: these are small code fragments (algorithms) that are used extensively by the parent application and are deemed essential to perform optimally,
- Skeleton apps: these apps reproduce the data flow of a simplified application and make little or no attempt to investigate numerical performance. They are primarily useful in investigating memory management, network performance characteristics, I/O, …,
- Mini- or compact apps: these apps contain the dominant numerical kernels contained in the parent application and represent the computational workflow in as compact a form as possible.

These proxy apps will be used both by the vendors and the rest of the exascale ecosystem to understand the effects of architectural trade-offs, but also by co-design code team members to explore new technologies, languages, algorithms and programming models. It is important to emphasize that these proxy apps will not be static, but will evolve significantly during the co-design process. The co-design centers anticipate the requirement for domain application code-developers to spend significant time with the vendors as well as vendor developers and architects to spend significant time with the co-design centers.

Vendor Interaction

The elements in the Workflow of Co-design are shown in Figure 1. The Computer Science, Applied Math and Domain Science research communities not only interact with the co-design cycle during the development of algorithms but also through the development of programming models, tools, simulators and the entire runtime environment. The central role of the Open Analysis is shown and the agile nature of each community's activity is shown as a continuous cycle. The arrows between the Application Co-design Centers and the Vendor and Software Stack communities show the intercommunication required for effective co-design. This intercommunication places important expectations on both the Co-design Centers and the rest of the exascale research ecosystem.

- The Vendors can expect the Co-design Centers to provide a suite of Proxy Applications that represents the complete workflow of the application domain. This proxy app suite should contain both documentation and a reference implementation that is amenable to co-design analysis using hardware simulators and prototype hardware. The suite of proxy applications is the main mechanism for the Co-design Centers to communicate the application requirements to the Vendors.
- The Open Simulation Environment offers the capability to create a Proxy Model of the Exascale Architecture and to simulate the behavior of the proxy apps on the model architecture. As shown in Figure 1, both the Co-design Centers and the Vendors are expected to participate in this open activity. The Vendors must provide the machine abstraction required for the simulators and programming models and they can expect a shared parameterization of the model experiment for use in their internal simulators and prototype hardware as well as integration of proprietary simulators. To start the process, several vendors are moving towards an open source hardware representation, e.g. LLVM.
- Trade-off results using the open simulation environment are expected to be openly shared between the Co-design Centers and the Vendors. However, results using proprietary simulators or internal Vendor analysis must be treated so as to preserve Vendor IP. Effective co-design still requires the Vendors to provide feedback to the Co-design Centers. This, for example, may take the form of guidance on how faithful the Open Simulation Environment represents the hardware abstraction.
- The Co-design Centers expect the Vendors to provide a set of hardware constraints based on the trade-off analysis with emerging hardware. The exascale community (including

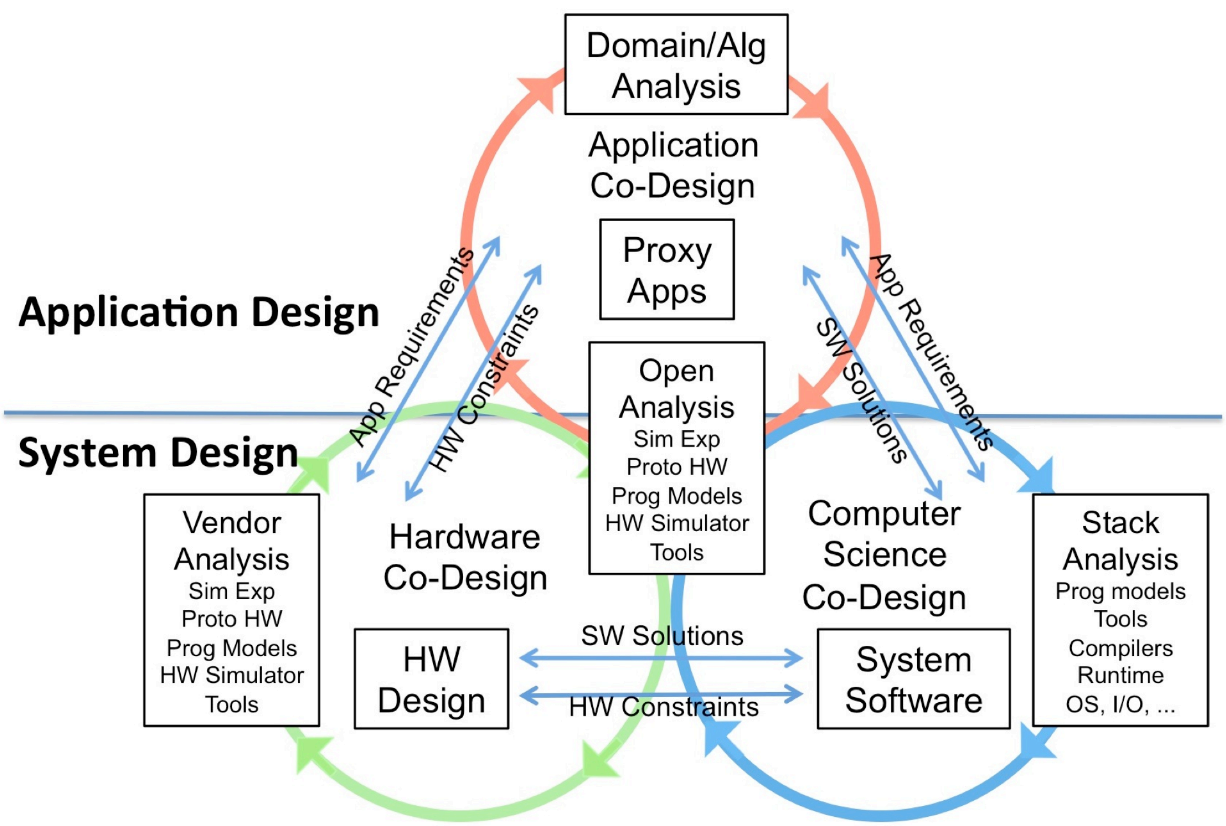

Figure1. Workflow of Co-design between Application Co-design Centers, Vendors, and the broader Research Community.

the Vendors) can expect the Co-design Centers to continuously update the proxy app suite based on the open trade-off analysis and the hardware constraints from the Vendors. These hardware constraints and the hardware abstraction are the main mechanisms for the Vendors to communicate the trade space to the Co-design Centers.

Open Co-design Questions

Extensive discussion with vendor representatives has demonstrated that significant progress towards exascale can be made through analysis of several open co-design questions. These include, but are not limited to:

- What is the balance between serial and parallel parts of algorithms?
- What are the byte/flop ratios of application codes?
- Are there algorithms that can tolerate lower byte/flop ratios?
- Are apps more amenable to many small cores or heterogeneous nodes?
- How much data must be moved (what are the required "speeds and feeds"), both intra- and inter-node (e.g. requirements on interconnect bandwidth)?
- Are there algorithms and programming models that minimize data movement?
- Are there algorithms that emphasize fine grain parallelism (strong scaling)?
- What is expected of runtime systems?
- How do we make compilers more application and data movement aware?
- Can vendors implement DSP style zero-overhead loops?

Exascale Co-design Centers

Brief descriptions of the co-design centers may be found at:
http://science.energy.gov/ascr/research/scidac/co-design/
For further details see:
Center for Exascale Simulation of Advanced Reactors (CESAR): http://cesar.mcs.anl.gov/
Center for Exascale Simulation of Combustion in Turbulance (ExaCT): http://exactcodesign.org
Exascale Co-design Center for Materials in Extreme Environments (ExMatEx):
http://exmatex.lanl.gov