High Performance Computing for Grand Challenge Problems

First Challenge: Exascale Computing.

The evolution, innovation and discoveries in most important disciplines as it could be climate change, energy, environment, national security, disaster preparedness and medicine depend on the pervasive and seamless availability of computing at scale. This is why new methodologies for power management at circuit, device and system level, locality and concurrency of data and the computations that use/generate it, and resilience to systems faults, are going to be crucial to development of this systems. Concurrent to this revolution is another paradigm shift in the quantity, quality and availability of digital data and its use in driving modeling and simulation. Finally, computing is increasingly data driven and conversely HPC is often constrained by the high volume of data it generates and consumes. High Performance Computers need to be more flexible on those terms and achieve a balance between the data handling capabilities and processing power.

Second Challenge: Core HPC Advances Needed for GB Communities.

It is necessary to have early and low barrier access to the best equipment, methodologies and software. Therefore there is an incredible amount of diversity of the applications addressed by NSF researchers, that diversity requires support for several kind of computational methodologies and computers that support different kind of researches and dictate the development of new methologies that would support this situation, a HPC should not only be able to meet the existing needs of the user community but also act as a driver for the development of effective strategies and tools for best use of the scientist.

Third Challenge: Software Stack – Programming Models, Compilers, Debuggers and Development Enviroments for Extreme Scales.

The Massage Passing Interface (MPI) based programming model has to be reinvented to meet the application challenges outlined in the application. New programming models must be developed to achieve this, this new models should allow the researchers to exploit the heterogeneity of processing elements and the hierarchy of memory and data storage need to be developed.

Fourth Challenge: New Numerical Algorithms to Efficiently Use Petascales and Exascale Architectures.

The scaling of supercomputers to millions of chips with thousands of cores per chip and the use of special use accelerators, graphic cards and data appliances will require the development of new algorithms and methodologies to deal with the fundamental shift in the computing and data storage and access architectures.

The next generation of codes will need to exploit the fain-grain parallelism at the intronode/socket level (Cores with shared memory and coherent caches) and the coarse—rain inter-node parallelism (nodes with relatively low bandwidth). Finally locality of data and avoidance of nonlocal memory references will be needed. New algorithms must be created that enable such methodologies.

Fifth Challenge: Data Flow and Data Analysis at Extreme Scale.

Many of the next generation grand challenges will be “data intensive”, that means that the ratio of data movement to computing required by such applications is quite different from that for computing intensive applications. This big volumes of data must be moved among processing elements and from secondary and tertiary storage, to enable this applications, it will be needed to pay special attention in the data flow amoung the interaction components of the application and the computing device. The most used data will have to remain next to the processing elements and available instantly