

Tools for Theory — High Performance Computing

Recent advances in understanding the basic building blocks of nature have led to a unified, but qualitative, description of physical processes from the smallest size scale, internal hadronic structure, to the largest scale, intergalactic structure. Scientists are now asking for a quantitative description, but such a description will require a very large increase in computer power. Presently, large investments are being made in basic research experiments. However, these investments will only yield their full return when corresponding, but much smaller, investments are made in the computational infrastructure.

An increase in computing capabilities of many orders of magnitude would enable major advances in fields such as high energy and nuclear physics, astrophysics, and general relativity, to name only a few. Increases in raw processor power need corresponding increases in memory, storage, data movement and input-output capabilities. Improvements in algorithms and software have advanced computational research as much as computing power. To take advantage of more powerful hardware, substantial efforts in algorithm and software development must be undertaken.

For example, in High Energy and Nuclear Physics, lattice gauge theory has made the greatest use of high performance computers. Currently, lattice simulations provide the only

means of obtaining accurate predictions of quantum chromodynamics (QCD). These predictions are important in order to make precise determinations of the parameters of the Standard Model, and to search for new physics within and beyond it. Recent improvements in algorithms and computational techniques, coupled with massively parallel computers, have brought QCD simulations to a new level of accuracy. More detailed predictions of the required accuracy for the properties of elementary particles and quark-gluon plasmas will require much more computer power.

Cosmology involves the study of the origin, structure, and evolution of the universe as a whole. New instruments have allowed detailed observations of the structure of the early universe. Computer simulations are required to understand fully the mechanisms that created this structure.

Lastly, theorists need increased computational power to solve the equations of the Einstein theory of gravity, since they are considered to be the most complex in all of physics. Gravitational wave observatories presently being built or planned are increasing the interest in this area. The separation of gravity waves from background noise demands precise calculations. Investment in the Strategic Simulation Initiative will bring great progress in a variety of theoretical areas mentioned above, but only if we make the corollary investment in the necessary data analysis.

