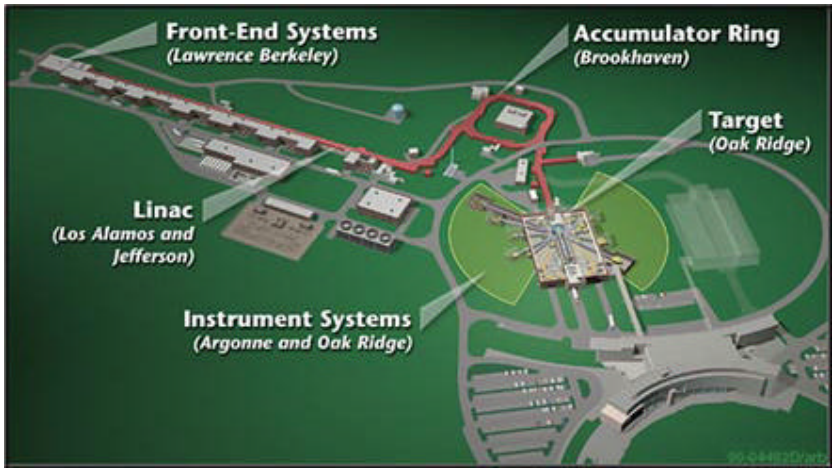
Next Generation Neutron Research Facilities Over Networks

Neutron research plays a fundamental role in improving materials that have a lot to do with our everyday lives: credit cards; pocket calculators; compact discs, computer disks, and magnetic recording tapes; shatter-proof windshields; adjustable seats; and satellite weather information for forecasts have all been improved by such research. Most of the world's neutron sources were built decades ago, for example, High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). Recently, the U.S. Department of Energy (DOE) Office of Science has funded the construction of a new, accelerator-based neutron source, the Spallation Neutron Source (SNS), which will provide the most intense pulsed neutron beams in the world for scientific research. In either case, the neutron sources are valuable national resources and represent some of the largest national science investments available to users from areas as diverse as chemistry, complex fluids, crystalline materials, disordered materials, engineering, magnetism and superconductivity, polymers, and structural biology. The next generation networks have the potential for providing an unprecedented access to these valuable resources to the users, but require capabilities significantly beyond the current Internet and ESnet.



Spallation Neutron Source

Powerful neutron beams will be produced in the SNS facility by bombarding a mercury target with energetic protons from a large accelerator complex. The protons will excite the mercury nuclei in a reaction process called spallation, releasing neutrons that are formed into beams and guided to neutron instruments. Using these sophisticated instruments, up to 50 of which will exist when the SNS is fully operational, scientists and engineers will explore the most intimate structural details of a vast array of novel materials.

The Network Challenge

The access to neutron sources, including SNS, is extremely expensive since users typically travel to the facilities to conduct experiments and carry the measurements back to their host institutions for further analysis. The *reliable remote control* of neutron sources represents a revolutionary advance in their usability: (a) travel to the facility is obviated, there by saving significant travel and coordination costs; (b) human operation is moved away from the potentially hazardous operational environments; and (c) costs and delays involved in conventional data transfers are eliminated. Such network based control methods have been attempted before, but achieved very limited success due to the inadequate and/or unstable capacity provided by the underlying network technologies. First, the required data rates are of the order of Terabytes/days, which are several orders of magnitude higher than the current Internet throughputs. As a result, at present the data currently is put on CDs and shipped using conventional means. A simple calculation shows that it takes about a year to transfer such data from ORNL to a university on the west coast. Second, the unpredictable network delays destabilize the control loops with potentially devastating consequences: an inordinate delay in a stop command to a neutron source can damage the subject and the facility, and an unstable control loop can result in the end-device crashing into the environment. The first problem of data rates can be addressed by building a faster network infrastructure, such as multiple OC 192 channels, together with high-performance data transport protocols. The network control technologies, on the other hand, require unprecedented advances since the current Internet and control technologies are inadequate for reliable and stable control. This problem is not solved by simply providing large bandwidths links, since the stability of end-to-end delays determines the effectiveness of control. While some recent daemon methods address these issues in a limited way, by and large, these problems are not addressed by the mainstream networking/control community, thereby necessitating indigenous research and development efforts targeting this area.

Elements of an Office of Science Program

The networking control and transport technologies required for these applications represent a significant advance in the area of high-performance networks and wide-area networks in general. In particular, the control technologies needed here enable the Office of Science to be a national leader in an important networking area in addition to making invaluable contributions to neutron scattering research programs.