Scientific facilities of the future

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Anticipated evolution of DOE complex In 10-30 years time frame, we anticipate scientific methods in DOE laboratories transforming drastically with autonomous experiments being mainstream, where AI will handle all the mundane tasks and a significant amount of specialized tasks. This transformation will make scientists much more productive, enabling them to tackle problems that are highly intractable now. We anticipate scientific computing needs requiring specialized architecture such as TPU, neuromorphic, graph processor etc for AI, or even user customized computing device in addition to general purpose systems (CPU and GPU). We expect quantum technologies including quantum computer, quantum network, and quantum sensors to be prevalent in the DOE complex in this time frame. The classical network connecting the DOE laboratories will evolve to support multi-petabit/s, allowing scientists to move an Exabyte across the country in under 1 hour in a 20 year time frame. 6G and 7G wireless network technologies will also pervade the DOE complex. The Figure depicts a portion of this future DOE complex. We describe our vision for the computing facility and networking below.

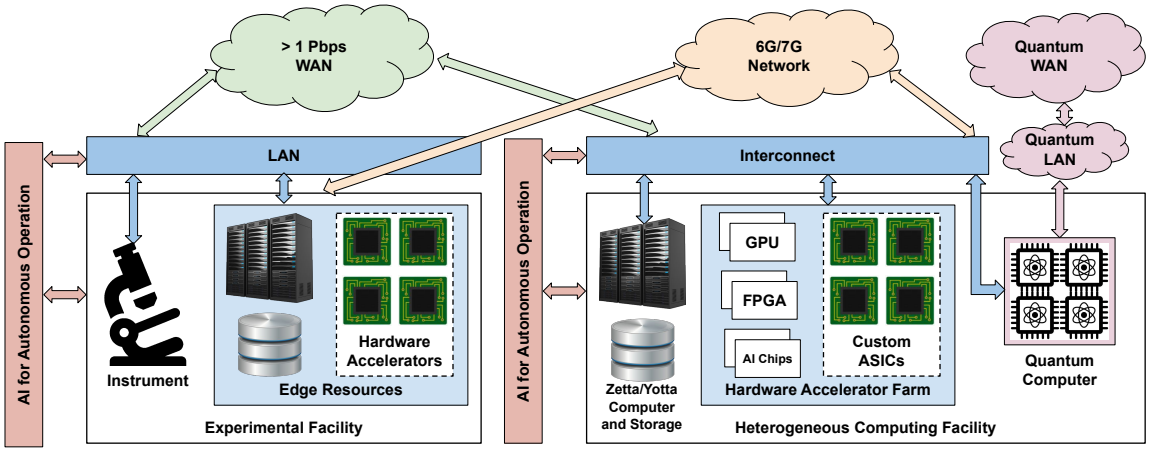

Figure 1: Scientific Facilities Architecture in 10-30 years.

Computing facility of the future Software engineering has evolved so much in recent years that building applications is much like assembling LEGO pieces to construct a toy. Based on developments in ASIC design and FPGA and the encouraging use of such developments (e.g, design of self-driving chip by Tesla), we anticipate that designing and manufacturing of specialized computing devices will evolve to become as easy as software development. Scientists will thus be ablke custom design computing devices for their scientific needs in 20-30 years. We envision DOE computing facilities hosting hardware containers and providing infrastructure needs such as power supply, cooling and network for these devices, in addition to hosting large-scale general purpose and specialized systems. We expect the specialized systems to include photonic chips as well. The facilities will allow users to ship containerized hardware, which will be placed in (or removed from) the container and brought up (or brought down) on-demand by robots.

Networking in 30 years Advances in wireless technology along with its increased adoption for scientific purposes, as well as the realization of quantum networks, will add significant heterogeneity to networking in the DOE complex. Such heterogeneity will lead to opportunities (e.g., added flexibility in the last mile with wireless, increased security with quantum) and challenges (e.g., high performance protocols for heterogeneous end-to-end connections). We anticipate that flexible spectral bandwidth will be used to improve network operations and to provide high degrees of quality of service. The raise of photonic chips will enable all-optical distributed computing at unprecedented speeds as we remove the barrier of eletro-optical conversion in network interface cards. Furthermore, in-network computing (with new protocols enabling them) could mature and become prevalent in that time frame.