Knoxville: Atomic Work, High-Energy Potential

Part I: The Atomic Advantage

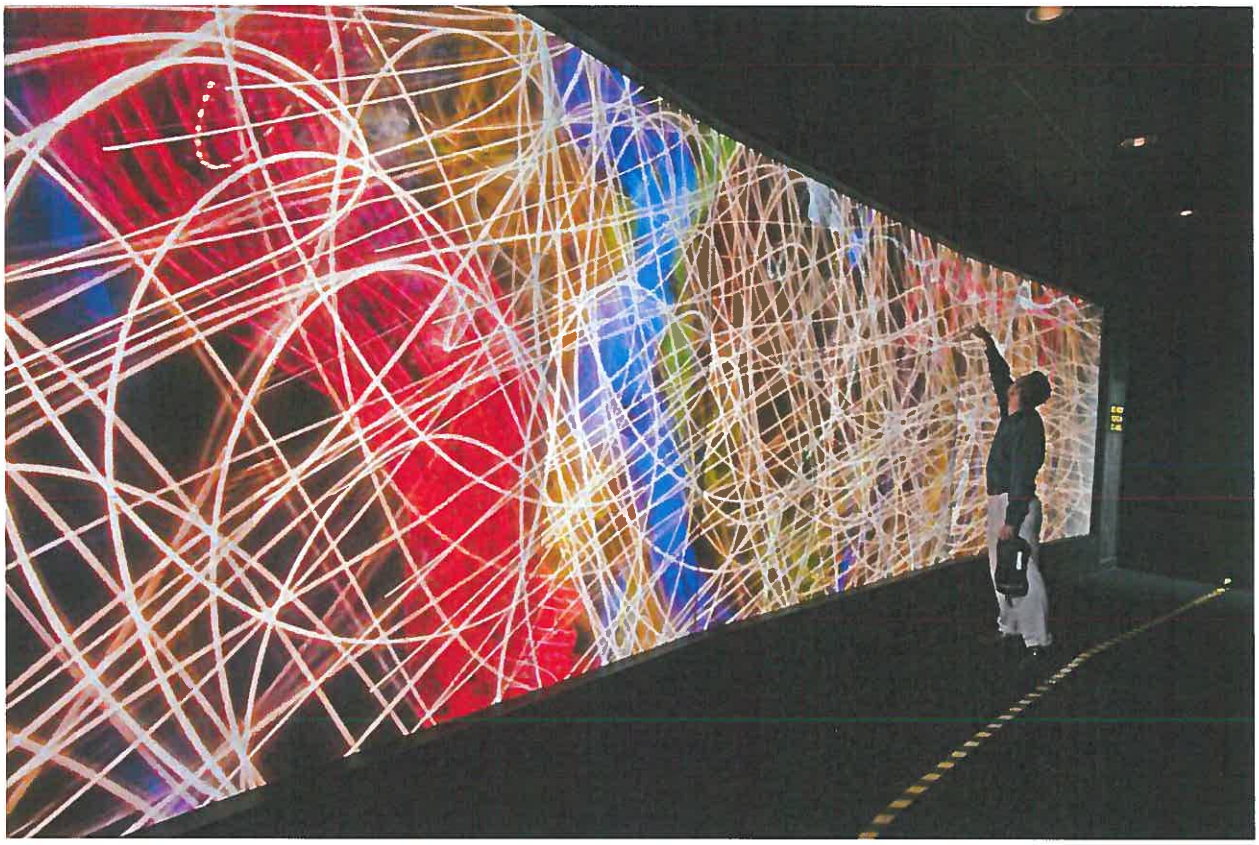

Image: The EVEREST Room powered by the Titan Supercomputer at Oak Ridge National Laboratory, Wikipedia

While the Oak Ridge National Laboratory may be located in "The Secret City", it is no mystery that ORNL is on the forefront in researching advanced technologies in neutron science, computation, materials, and renewable and nuclear energy. ORNL is the largest science and energy lab in the United States and employs 1,600 scientists and engineers along with 3,000 guest researchers in more than 100 disciplines while operating on a budget of $1.65 billion.[20] As of the year 2000, the University of Tennessee, Knoxville and Battelle have maintained a 50-50 limited liability partnership to manage operations at ORNL and to achieve the research goals set by the Department of Energy. Whether the numerous research groups are dedicated to better understanding the

nature of quantum mechanical systems or overcoming challenges in national security, the researchers at ORNL are working to implement the infrastructure necessary for the general public to live in a safer, more efficient, and technologically advanced community.[20, 21]

Although ORNL's research efforts are as various as they are impressive, a significant portion of their research is dedicated to advanced materials and nuclear science for the generation and storage of energy. The United States, along with other nations around the globe, will require more energy while simultaneously seeking alternative, cleaner, more sustainable forms. Although the amount of fossil fuels left available for global usage could be considered a matter of debate, the impact on the environment due to the burning of fossil fuels is not. In any event, the matter of finding alternative forms of energy while still meeting national and international power consumption is necessary. Likewise, a similar set of challenges to overcome in the realm of energy, in addition to the creation of energy, are the storage and transfer of energy. At ORNL, technological solutions to both of these challenges are being sought, as the advanced materials research efforts are focused both on the development of new materials while simultaneously improving the performance and lowering processing costs of materials. Through this combined effort, ORNL is and will continue to be one of the forerunners in developing state-of-the-art technologies for both the generation and storage of energy within the United States and internationally.[22, 23, 24, 25, 26]

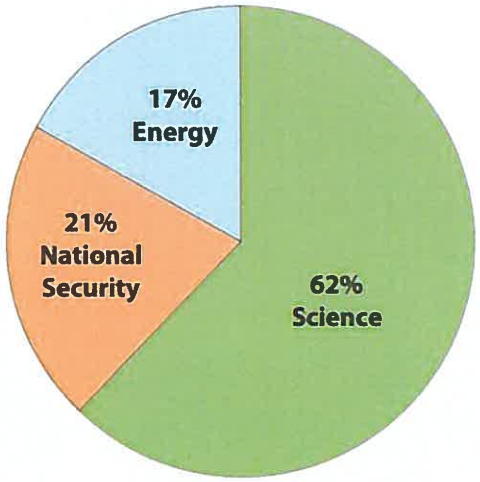

Fig. 2: Composition of ORNL's research portfolio.[20]

As a whole, Tennessee's advanced energy industry is one of the strongest in the nation, employing approximately 375,000 people with a 17.6% growth in employment since 2010, outpacing the national average of 13.7%. From 2015 to 2025, the employment within this industry is expected to grow an additional 13.2% with 24,530 establishments already directly involved in the advanced energy industry. Tennessee is also No. 2 in the nation for energy reliability and smart grid deployment, due to TVA achieving 99.999% reliability every year since 2000. In total, the advanced energy industry generates $33.4 billion for the GDP solely for the state of Tennessee.[40, 51, 52]

ORNL however, is not alone in its matters of national security and nuclear fuel resources. The Y-12 National Security Complex is also situated on ORNL's campus and is dedicated to developing advanced technologies related to nuclear energy and national security along with performing work for other government and private sectors. The Uranium Processing Facility on site is used frequently to store nuclear material and to process old nuclear weapons for the purpose of extracting the valuable contents and using them to fuel the nation's naval reactors. Another partner at ORNL, the Electric Power Research Institute, Inc., is dedicated to researching and developing innovative solutions for the generation, transportation, and storage of electricity.[33, 34]

While research in all disciplines has been performed for thousands of years simply through lab-based experiments and trials, computers, in some instances, are simultaneously able to serve as both a cheaper and extraordinarily informative alternative to traditional experimentation. Some of the biggest challenges in energy solutions, advanced materials, quantum mechanical systems, transportation, and climate change, can be approached through the usage of computational methods. At ORNL, the usage of the Titan supercomputer is fundamental for modeling these complex systems. The Titan was also ranked as the No. 1 supercomputer at the time of its establishment in late October of 2012 and as of the latest TOP500 ranking in November 2015, Titan still holds the No. 2 position of the TOP500 supercomputer ranking project. For modeling the complex challenges of the future however, even the Titan is not enough. In response, ORNL will be replacing the Titan with their newest addition, Summit, which will have a peak performance of over 100 petaFLOPS and is to become operational in the year 2018.

In comparison, Titan has a peak performance over 20 petaFlops, meaning that the Summit will be about five times more powerful than the Titan.[27, 28, 29, 30, 31]

As with any scientific or technological pursuit, researchers and entrepreneurs alike within a particular field are aware that innovative ideas can often be found outside of their specific discipline. Likewise, ORNL fully recognizes the importance of interdisciplinary collaboration, and consequently maintains a number joint institutes with the University of Tennessee, Knoxville and Vanderbilt University pertaining to the biological, computational, neutron, nuclear, and material sciences. Due to UTK's partnership with ORNL, the university has been classified by the Carnegie Commission as a "research university with very high research activity (RU/VH)".[21] ORNL has also formed additional partnerships with more than 250 universities across the nation to both train and excite young undergraduates and graduates for the future of scientific innovation. [20]

Along with ORNL promoting an interdisciplinary environment on their campus, ORNL plays a key role in two "Innovation Hubs". The two hubs, the Consortium for Advanced Simulation of Light Water Reactors and the Critical Materials Institute, focus on the advanced modeling and simulation of nuclear reactors and technologies that enhance the performance of already existing materials along with finding alternatives to materials that are subject to large fluctuations or disruptions in supply. ORNL also hosts a number of other centers, institutes, and laboratories on their campus to pursue a variety of scientific endeavors.[32]

As a whole, the relationships amongst UTK, ORNL, Y-12, and the EPRI is collectively known as The Knoxville-Oak Ridge Innovation Valley. Together, they are a center for scientific innovation within the Southeast, specifically in the state of Tennessee, and have exceptional potential for providing the next generation of technologies for the future. Outside of ORNL however, Knoxville also has the Knoxville Entrepreneur Center (KEC) dedicated to turning ideas into working products and businesses. Through the various accelerator programs, entrepreneurs can take their ideas or products at different stages and slowly develop them into profitable startup businesses.[41] Whether the development period exists as a short time span of 48 hours or a 12 week training program, the KEC is helping entrepreneurs connect with investors and move their businesses to the next

stage.[37] In addition, UTK has the Anderson Center for Entrepreneurship & Innovation to expose students to the fundamentals of entrepreneurship while simultaneously providing them with access to mentors and the necessary resources to mould their ideas into profitable businesses.[39] Tech 2020, a public-private partnership established in 2000, is yet another program funded by UTK, ORNL, and Y-12 to promote new business development and economic growth which has created 2,000 jobs and made a $275 million impact on the region.[42] Overall, through the combination of ORNL, the KEC, and the various accelerator programs and entrepreneurship centers within the Knoxville area, there exists a healthy business climate to promote entrepreneurship and innovation for developing the ideas within the population of Knoxville and the surrounding areas.[35, 38, 40]

Part II: Knoxville, Beyond the Data

For Tennessee to maintain a Silicon Valley-like environment, the operations at ORNL and Innovation Valley are crucial to promoting entrepreneurial pursuits and economic growth and development. As the number of devices begins to increase with the growth of the IoT movement, electricity generation and storage will become an increasingly important issue. Batteries and electronics for devices that are wearable, washable, and ultimately durable, will be a necessity for the future of IoT. Both the processing and operation of these devices will need to be improved, as the next generation of handheld and wearable devices will be constantly communicating with each other, relaying data and dynamically adapting to user input.

Although these devices will be small, they will nevertheless be numerous and, as such, must be manufactured appropriately. These devices will constantly relay sensitive information about its user, thus making the secure transfer of this relayed information perhaps the number one challenge for IoT. If the encryption algorithms used for these numerous devices are not secure, countless privacy and security issues will arise, with knowledgeable and even amateur hackers being a significant source of criminal activity in the future. ORNL, with 21% of its research dedicated to national security, will play an important role in internet and electronic security for over 300 million United States citizens. [20]

While IoT will require smaller batteries and electronics, there still exists the issue of providing the necessary power for the more complex systems of the future. Given that ORNL is largely dedicated to the study of fusion energy, researchers at ORNL could be some of the various research groups around the globe to better understanding this technology. A global program titled International Thermonuclear Experimental Reactor (ITER), could provide an alternative source of enormous amounts of energy with no greenhouse gas emissions, no long-lived radioactive waste, no risk of nuclear meltdown, and no potential for nuclear proliferation.[25, 43, 44] Additionally, there is potential for ORNL to create innovations in solar technology that will be capable of much higher quantum efficiencies, causing solar to be a more affordable option for everyone. Users with improved solar panels, in combination with improved battery storage, will become

self-sustaining entities, relying less and less on a central grid for power or even being producers of electricity that can be transferred to other residential areas connected through the same local power grid. Solar panels are only one example however, as there are likely multiple different types of materials and chemical reactions currently being tested at ORNL for their conductive and electricity generating potential, respectively.

All this research will ultimately require a number of trials and various experimental testing conditions to determine materials with the highest potential of becoming the next building-block of future electronic devices. To pursue this research however will require an extensive amount of funding, as the starting materials and testing conditions are as expensive and intensive as the experiments are numerous. If multi-variable, multi-particle systems can be simulated through the use of a more powerful supercomputer, this will significantly reduce the amount of lab-based experiments that will need to be run, allowing a number of failed experiments to be circumvented while only performing experiments that are highly favorable for total product yield or whose theoretical probability of success is particularly high.

Even for a supercomputer such as Titan or Summit however, there is an eventual classical limit to the fundamental composition and operation within traditional processing. Transistor size on a microchip is slowly approaching a classical limit, signaling that the end of Moore's Law is likely near, being slowly replaced by Rose's Law for qubits in a quantum computer.[50] To date, the smallest transistor technology capable sits at 14 nm, with the speculated physical limit being 5 nm.[47, 48] However, if a true quantum computer can be developed and implemented at ORNL, it will have serious potential to solve particular problems, specifically discrete optimization problems, much faster than any classical computer or supercomputer would ever be capable of. A quantum computer would also make certain data encryption methods obsolete while simultaneously creating a new type of encryption method, specifically the BB84 protocol, providing a useable and effective method of Quantum Key Distribution (QKD). The question for ORNL, then, is not if it will ever have a quantum supercomputer, but when the time will come when a true quantum supercomputer is developed, implemented, and utilized to accelerate the discovery of new scientific innovations while simultaneously lowering the cost of experimentation.[45, 46, 49]

Collectively, the environment created by ORNL and the surrounding institutes, universities, innovation hubs, entrepreneur centers, and various other programs, allow the Knoxville region to play a serious role in the development and manufacturing of state-of-the-art technologies that will significantly change the day-to-day operations of normal private and public life for the entire globe. For Tennessee as a state, this collection of institutions is a significant factor in creating the most optimal, Silicon Valley-like environment.