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CHAPTER 2: ENGINEERING LEADERSHIP

INDUSTRY ANALYSIS

Our capstone team has partnered with The SLAC National Accelerator Laboratory (SLAC), located in Menlo Park, California, with the goal of improving the operational efficiency of the linear particle accelerator (linac). Specifically, our team project involves predicting events and features that could potentially lead to linac failure and idleness.

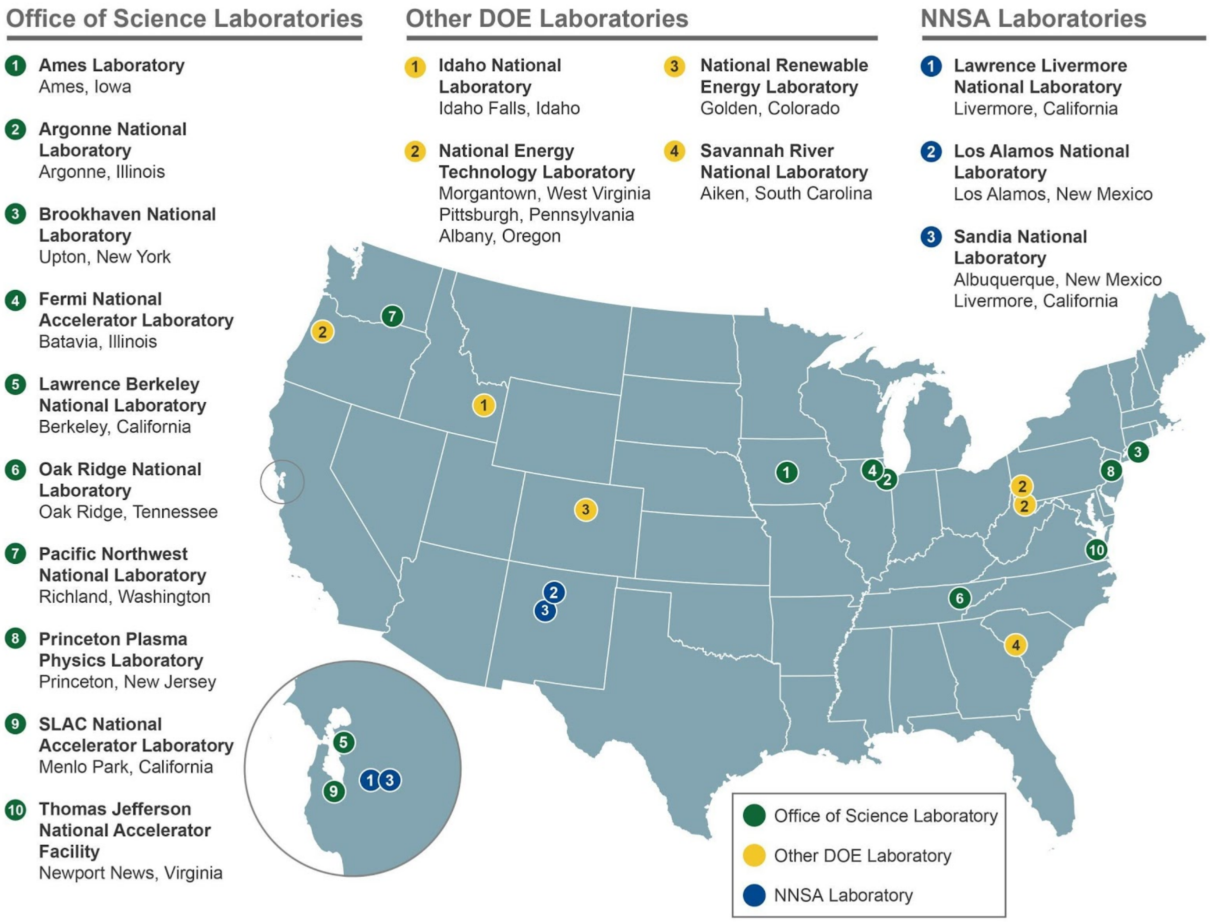
Over the past several years, accelerator facilities are shutting down before new ones are opening, and thus restricting the opportunity for experiments and creating great uncertainty about future funding.[1] That said, the results of our project are aimed at improving linac operational efficiency to increase the number of annual research experiments, as well as reduce operational expense.

SLAC's main industry is large, nationally-run, research facilities and laboratories; the industry can be further divided into two, related yet distinct, subsets:

1. United States Department of Energy (DOE), Office of Science Laboratories' (OS) cohort of 10 domestic research facilities.
2. The global collection of large particle accelerators primarily used for scientific research.

The first subset is determined by DOE funding and oversight; the OS stewards a particular set of research facilities that support the organization's mission and science programs. Please see Figure 1.1 for a national map of all DOE laboratories. The second subset includes the 101, large scale particle accelerators located around the world, of which 36 are located in the United States.[2] These particle accelerators are typically classified by type, including electron, proton, light and heavy ions, and colliders; originally classified as a collider, the SLAC linac is currently considered an electron accelerator.

Figure 1.1



Source: [*https://science.energy.gov/~/media/_/images/laboratories/DOE_Laboratories_Map_2014_Hi-res.jpg*](https://science.energy.gov/~/media/_/images/laboratories/DOE_Laboratories_Map_2014_Hi-res.jpg)

Although SLAC has much experience performing machine learning in the scientific research space, such analysis on the operations of the linac is nascent, and consequently our capstone project addresses this important issue. The team believes that our research and analysis can create a process to allow the apparatus to detect future failure events, diagnose the cause, and ultimately tune itself. These improvements are aimed to increase efficiency in operations and yield higher number of experiments annually. This efficiency can start to reshape the industry by reducing human operation error and labor maintenance intervention. From an economic perspective, the increase to efficiency should lead to a reduction in repair and maintenance costs, and possibly reduce maintenance headcount for facilities operations.

The barriers to entry in this particular industry are high. The subject matter expertise (physics and engineering) required to design, the large upfront capital costs to construct (typically $millions/billions), and the necessary funds ($millions) to annually maintain these facilities, all lead to a few global competitors. Hence, a majority of large research laboratories are supported and funded by federal governments. As for competitors, The European Organization for Nuclear Research (CERN; operator of the world's largest Large Hadron Collider), located in Meyrin, Switzerland, and The GSI Helmholtz Centre for Heavy Ion Research, located in Darmstadt, Germany, are considered as competing research facilities. To maintain SLAC's competitiveness on the global stage, the DOE's Office of Science Laboratories has budgeted $2.1 billion for 2019; specifically, $760 million has been allocated to fund the Linac Coherent Light Source-II High Energy project.[3]

Conversely, the competition within the scientific research community to use the facilities powered by the accelerator, is extremely high; typically, there are thousands of applications annually and if selected, there is a two (2) year waitlist to run and utilize the SLAC facilities.

MARKETING STRATEGY

Pursuant to the Industry Analysis section, our target markets would entail: (1) the research facilities funded by the DOE's Office of Science division and (2) the other 101 particle accelerators located around the globe. In terms of value creation, both the agencies that fund and the operators that oversee management of such research facilities would find interest in our predictive algorithms and approach/framework. Specifically for SLAC, the value proposition for the management team comes in the form of increased accelerator uptime, resulting in more experiments processed/scheduled. The increase in experiment yield should result in a higher number of research proposals received, ultimately increasing SLAC federal funding. In addition, the propensity for new ground breaking discoveries allows the federal government the ability to access transformative technologies and maintain scientific competitiveness on a global basis.

Commercialization of our capstone technology is somewhat problematic given that the algorithms are tailored specifically to SLAC. A more realistic approach to commercialization would be via a services platform whereby consulting services would be performed by a team of engineers and project managers; the target audience would initially be various particle accelerator facilities around the world, and then expanding to other "tertiary" research facilities requiring predictive analytics regarding machine failure; examples include nuclear power plants, large scale desalination plants, and large petroleum refineries to name a few. The team believes that our general approach to problem solving SLAC's machine failure issue is generally broad, and replicable, enough to add value to various organizations with relatively low lift, as the services business scales.

SOCIAL CONTEXT

Particle accelerators will be responsible for new and exciting discoveries in these areas that shape our view of the planet and universe: Higgs and the explanation of particle masses, supersymmetry, dark matter, extra dimensions, and the unification of fundamental forces.[4] As the world’s longest particle accelerator (3.2 kilometers), SLAC research has yielded four Nobel Prizes and has led to many groundbreaking discoveries in physics including the charm quark, tau lepton and quark structures.

In its new role as the engine that powers the Linac Coherent Light Source (LCLS), the SLAC linac supports hundreds of scientists each year conduct groundbreaking experiments into the fundamental processes of chemistry, materials and energy science, biology and technology. LCLS experiments generated more than 600 articles in peer-reviewed scientific publications in the first six years of operation, with almost a quarter of them appearing in prominent journals like Science and Nature.[5]

In chemistry, “molecular movies” made with SLAC’s X-ray laser are capturing all the tiny steps of chemical reactions for the first time. This new understanding will help improve reactions that give us fuels, fertilizers and a host of other products. In biology, X-rays reveal how proteins – one of the key molecules of life – function in the human body and in nature. This research has contributed to the development of medications for melanoma, flu and HIV and is aiding the fight against Ebola, high blood pressure and other ills.[6]

Additionally, SLAC has a continued and important role in the development of new technologies, and maintains a deep and enduring commitment to the training of tomorrow's scientists and engineers.[7] Our team’s machine learning work should increase the number of proposals and experiments at SLAC. Any number of these cutting edge experiments can have a profound effect on our society and our basic understanding of the world. This can give rise to new industries and technologies, driving both research and the local, national and global economy.

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7. Jean Marie Deken (2003). Future Proof for Physics: Preserving the Record of SLAC, https://arxiv.org/pdf/physics/0308021.pdf

Additional Links

DOE Office of Science Annual Budget - SLAC [here]
DOE Official SLAC site [here]
Advancements in the Energy Frontier [here]
Accelerators for America's Future [here]
New Discoveries based on accelerator experiments [here]
SLAC Overview [here]