Developing fusion power is a complicated endeavor, requiring the world’s sharpest minds. The Princeton Plasma Physics Laboratory (PPPL) is fulfilling the promise of fusion energy by developing the science and engineering solutions the world needs to make fusion power plants commercially viable.

**Optimizing the Magnetic Confinement System**

It takes immense heat and pressure to generate net energy from a fusion reactor. To achieve fusion, the plasma needs to reach a high temperature while confining the energy in the plasma for as long as possible. Magnetic confinement systems are machines that use magnetic fields to create the right conditions for fusion reactions to occur in a plasma. Perfecting these devices to be able to produce cost-effective fusion remains an active area of research. PPPL is a leader in exploring the most promising magnetic confinement systems, including two types of devices known as tokamaks and stellarators.
Developing Models and Measurements to Predict, Optimize and Control Fusion

During a fusion reaction, the plasma needs to be well confined and controlled to efficiently sustain the reaction. PPPL uses advanced physics and engineering models, the world’s most powerful supercomputers, artificial intelligence and machine learning to address these scientific challenges. The Lab has long retained a leadership position in terms of understanding, predicting and optimizing fusion performance and in actively controlling plasmas to avoid instabilities that can reduce fusion power. PPPL is also a leader in developing and deploying advanced diagnostic systems for measuring key plasma parameters and dynamics. These diagnostic systems are used in devices around the world to validate predictive models and control high-performance plasmas in harsh fusion environments.

Taming Interactions Between the Plasma and the Reactor Walls

Even when confined inside a fusion reactor’s high-powered magnetic fields, plasma doesn’t maintain a perfect shape. Just as the plasma that makes up the sun sporadically jets out, so does the plasma in an Earth-bound fusion device. These tendrils of plasma can touch and potentially damage the reactor’s walls. PPPL is working on several methods to increase the resilience of the wall, including real-time mass injection of solid boron or lithium to reduce harmful plasma ejections to the wall and on liquid lithium walls when intense plasma contact does occur.

Designing Superconducting Magnets That Can Withstand Years of Use

The ability to generate a very high magnetic field over a large volume of super-hot plasma with minimal power consumption is challenging. Yet, this is a fundamental requirement for all magnetic confinement fusion concepts. PPPL’s unique superconducting magnet laboratory is developing systems that will produce magnetic fields far more powerful than those produced by our planet. The magnet lab’s research could lead to stronger, more compact and more efficient magnets, which, in turn, may reduce the size and cost of tokamak and stellarator fusion systems.