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AI Brings Fusion Power Plants Closer to Handling the Unexpected

DIII-D demonstrates machine learning that adapts to equipment problems while keeping plasma under control.

CHICAGO—Future fusion power plants will need to do more than produce energy. They will also need to operate reliably when equipment does not perform exactly as expected. New research at the DIII-D National Fusion Facility is pointing to a solution. In recent experiments, researchers demonstrated a machine-learning approach that helped the fusion control system adjust in real time when presented with sudden changes. The results offer a potential path toward making future fusion power plants more reliable and better prepared to provide electricity to the grid.

"Most people never think about everything happening inside a power plant," said Andy Rothstein, a researcher at Google DeepMind. "They simply expect the equipment to work when they need it. If fusion is going to become part of our everyday energy supply, it will need that same level of reliability. This research brings us another step closer to that future."

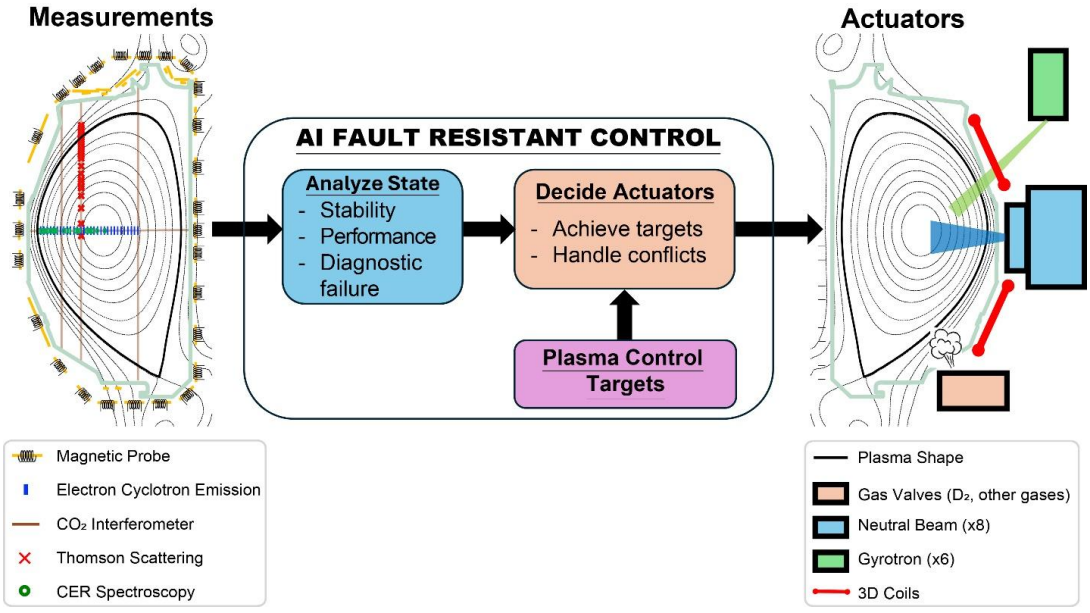


Figure 1: The Electron Cyclotron Heating Optimizer (ECHO) is a machine learning tool deployed at DIII-D that uses inputs from different measurement systems to analyze the plasma state. From the analysis results, ECHO determines which actuators to adjust to maintain plasma stability.

As part of his doctorate work at Princeton University, Rothstein evaluated what would happen if part of a system used to heat plasma in the DIII-D tokamak went offline. Instead of waiting for an operator to manually adjust the remaining equipment, the machine-learning system responded in real time and shifted the work to heating sources that were still available.

The technology, known as the Electron Cyclotron Heating Optimizer (ECHO), helps coordinate powerful microwave heating devices called gyrotrons (Figure 1). These devices direct energy to specific areas inside the plasma, giving researchers an important tool for controlling plasma behavior. Future fusion power plants will need systems that can make these kinds of adjustments quickly as conditions change.

ECHO uses machine learning to determine how the available gyrotrons should be directed so heating continues to reach the proper locations. When individual gyrotrons were taken offline during experiments at DIII-D, ECHO reassigned the remaining heating sources and maintained the intended heating pattern. The results demonstrated that the approach could adapt even as equipment availability and plasma conditions changed.

That ability could become increasingly important as fusion moves toward power-producing systems. DIII-D's flexible controls allow researchers to test machine-learning approaches directly on a fusion plasma, helping develop systems that can respond quickly and reliably when conditions change.

"The real promise of this work is giving fusion systems more ability to handle problems on their own," said Rothstein. "That kind of adaptability will be essential as fusion moves from the laboratory toward a dependable source of energy."

ECHO is part of a broader effort at DIII-D to develop machine-learning tools that can help fusion control systems respond faster and more reliably as conditions change. Researchers will continue advancing these tools with the goal of preparing future fusion systems to keep operating when the unexpected happens.

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Abstract

JI02/1 ML-Enabled Fault Resistant Plasma Control on DIII-D
Session JI02: Integrated Modeling, Optimization, and Plasma Control
9:30 AM–12:30 PM, Wednesday, November 4, 2026
Room: Hilton Chicago, International South, Second Floor