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Driving fusion success: target diagnostics software control at National Ignition Facility (NIF)

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Achieving controlled nuclear fusion at the National Ignition Facility (NIF) depends not only on precision lasers and target engineering, but also on a robust suite of target diagnostics systems. These diagnostics capture critical physics data—including neutron yield, burn width, symmetry, and x-ray emissions—essential for guiding the path to ignition. Central to this capability is the target diagnostics software control system synchronized to within tens of picoseconds of each laser shot. It coordinates nearly 100 diagnostics and over 600 software-controlled instruments, including high-speed sensors and radiation-hardened devices operating in extreme environments. A major challenge is supporting diverse, evolving hardware from multiple vendors using protocols like serial, Ethernet, GPIB, and proprietary APIs. The software architecture addresses this through centralized orchestration, abstraction layers, and hardware adapters. The system's flexibility is demonstrated in the successful deployment of the VISAR (Velocity Interferometer System for Any Reflector) diagnostic, which integrates varied vendor instruments —cameras, lasers, delay generators —with custom interfaces and precise synchronization. Long-term use has revealed challenges with aging, vendor-specific systems and managing radiation-hardened devices. Future improvements will enhance resilience, sustainability, and integration of next-generation diagnostics.

Footnotes

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