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Scalable KSTAR Real-time Diagnostic Infrastructure Supporting Disruption Prediction and Avoidance

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The KSTAR (Korea Superconducting Tokamak Advanced Research) DPA (Disruption Prediction and Avoidance) project led by Steve Sabbagh and Columbia University established a need for increased real-time diagnostic inputs to the KSTAR PCS (plasma control system) to support the real-time evaluation of DECAF (Disruption Event Characterization and Forecasting) algorithms. Over several years, the DPA project installed real-time acquisition of MHD (magnetohydrodynamic), ECE (electron cyclotron emission), and ECEI (ECE imaging) diagnostics, while starting development of a real-time version of vPhi charge exchange Spectroscopy. Each diagnostic shares a common real-time infrastructure that has scaled well between multiple computers and across scientific domains. For example, MHD uses an FPGA, ECE and ECEI use analog digitizers, and vPhi uses a camera system. The various computers communicate over a low latency, high throughput, real-time safe native PCIe link while maintaining compatibility with the existing KSTAR PCS system and its RFM (reflective memory) communication technology. The software framework includes a real-time OS, instrumentation tools, interfaces for archiving and real-time concurrency, and specific I/O device controls. The software also interfaces with PCS itself, with parts of the core PCS running on each real-time system providing entry points for new diagnostic data. This system ran successfully in the 2021 and 2022 campaigns and demonstrated efficient scalability between fundamentally different diagnostic and scientific needs. Each diagnostic, the interconnect, and the underlying software environment will be described with respect to real-time characteristics.

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