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Accelerator digital twin development through simulation modeling and MLOps using the LUME ecosystem at SLAC

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Accelerator digital twins can enable real-time optimization and predictive control helping streamline complex facility operations and reduce setup time. Machine Learning(ML) models can enhance digital twin capabilities by leveraging prior experiments, known parameters, and real-time measurements. These require robust infrastructure and open-source software tools for accurate beam modeling and system integration. SLAC has developed the Lightsource Unified Modeling Environment (LUME) to enable large-scale modeling of X-ray free electron laser performance. The team is developing an ecosystem of tools towards start-to-end simulations for a much broader set of accelerators beyond light sources. LUME components include python wrappers for physics simulation which also work with a snapshot of the current accelerator reading through Kafka. LUME-services offers core infrastructure for model workflows including contextualized file service, model and results databases, and scheduling via Prefect for automated runs. LUME-Model holds the data structures used in the LUME modeling toolset, encapsulating physics simulations and ML models. LUME-EPICS is a dedicated API for serving LUME model variables with EPICS. MLflow is being integrated to manage the full machine learning lifecycle. This infrastructure is currently being developed and deployed at SLAC, alongside collaborators from other laboratories (especially LBNL). Here we provide an overview of the LUME ecosystem and example use cases.

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Footnotes

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