Improving Tokamak Operating Efficiency through Actuator Modelling with LSTMs

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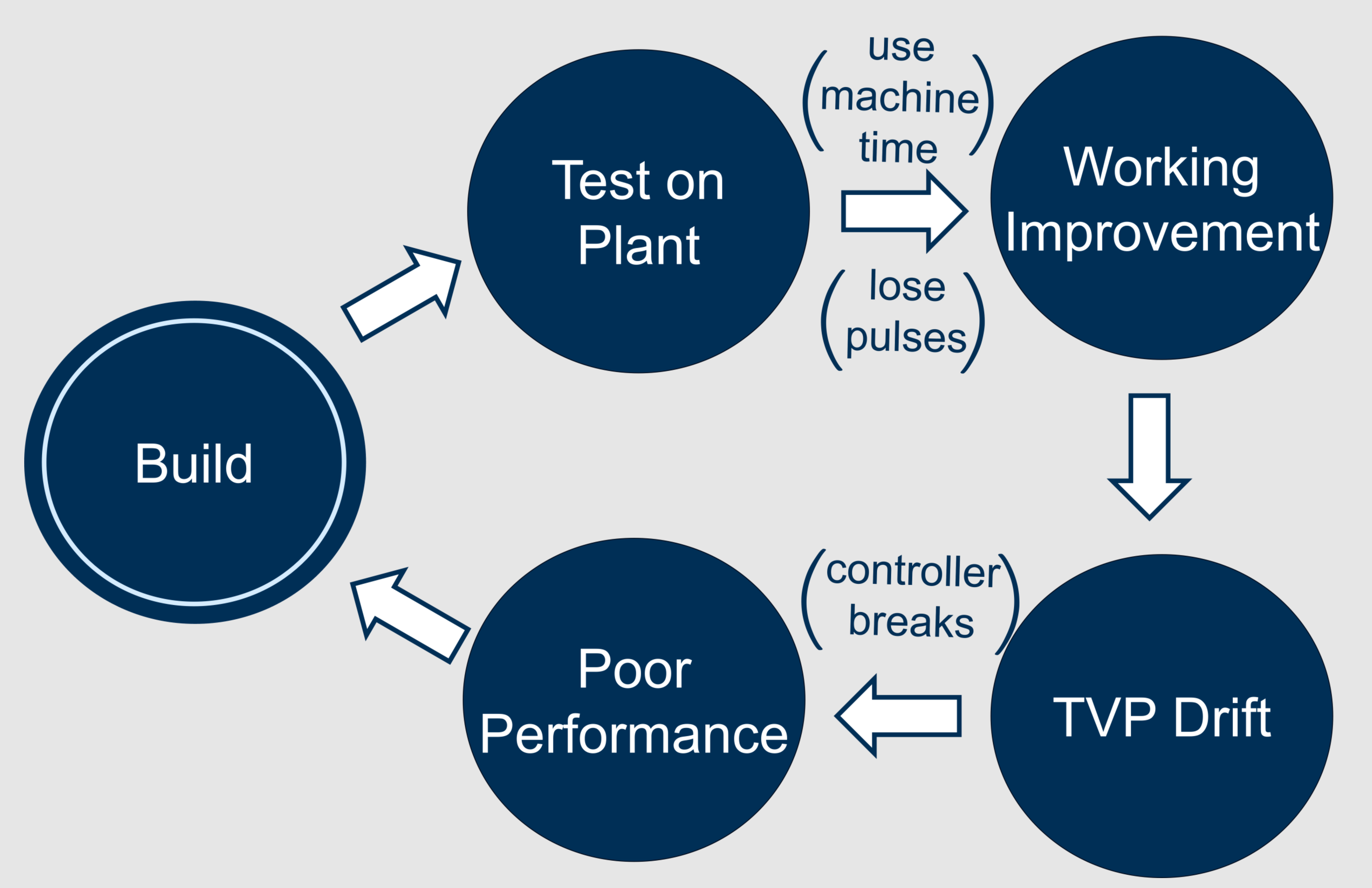
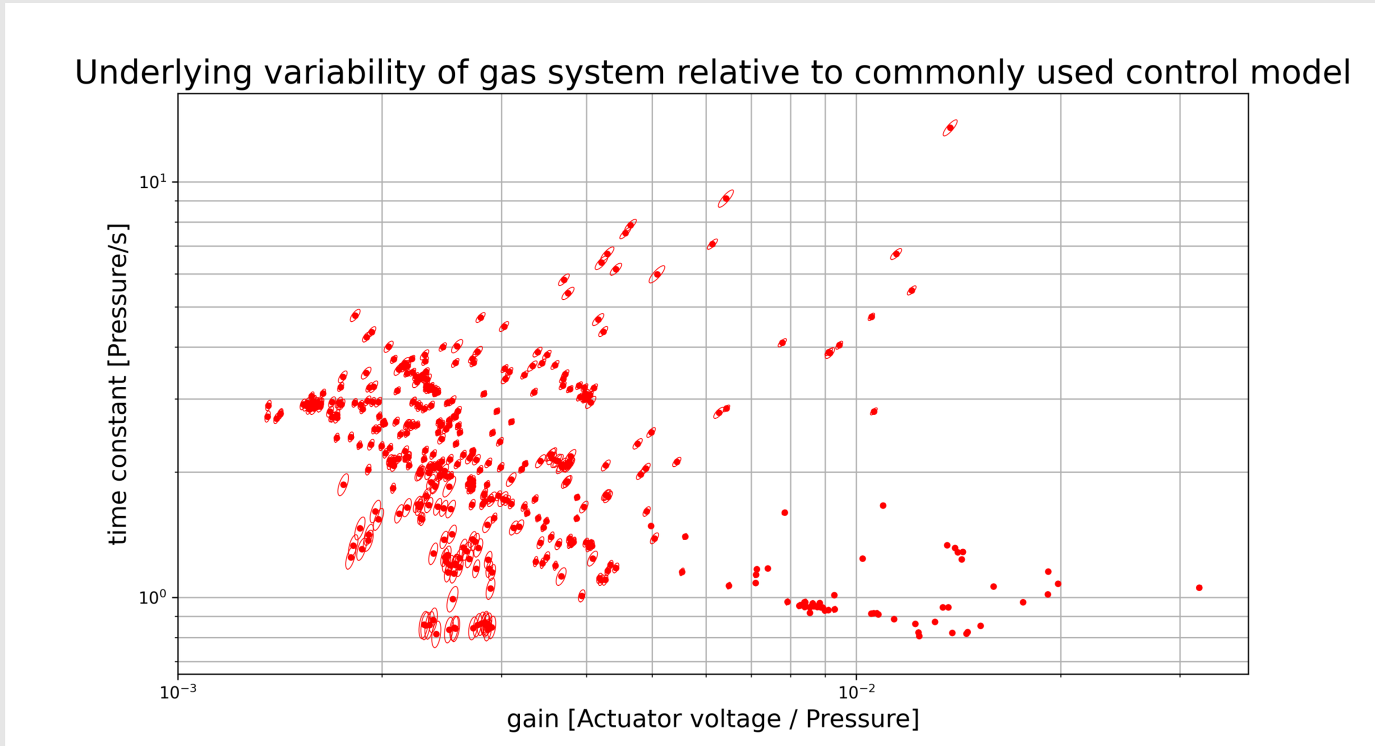
1 PROBLEM STATEMENT

Variability in response of tokamak actuators to actuation commands adds uncertainty to every experiment.
This uncertainty is easily overlooked.
Gas systems installed on JET (and ITER) have time-varying parameters that must be manually calibrated for.
This leads to a wasteful controller tuning cycle.
This work aims to break the development pattern and provide a basis for a model to test controllers against.

2 VISUALISING THE SYSTEM



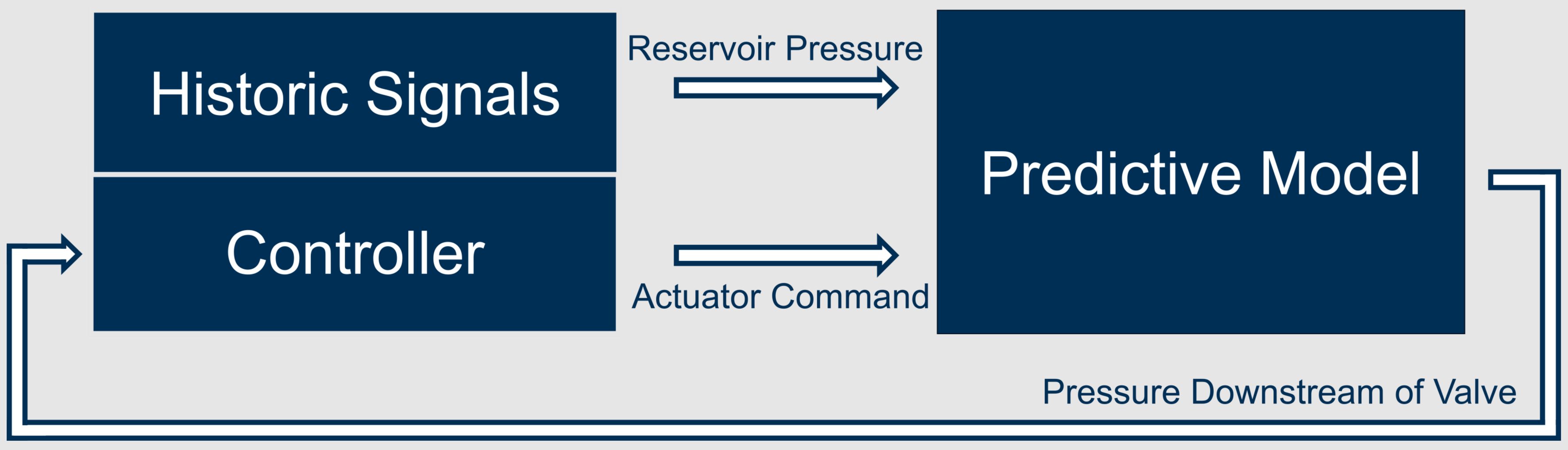
Controller Development Cycle



The parameters of a linear system change significantly over pulses, which shows there is an underlying time-varying parameter.

3 PROPOSED SOLUTION

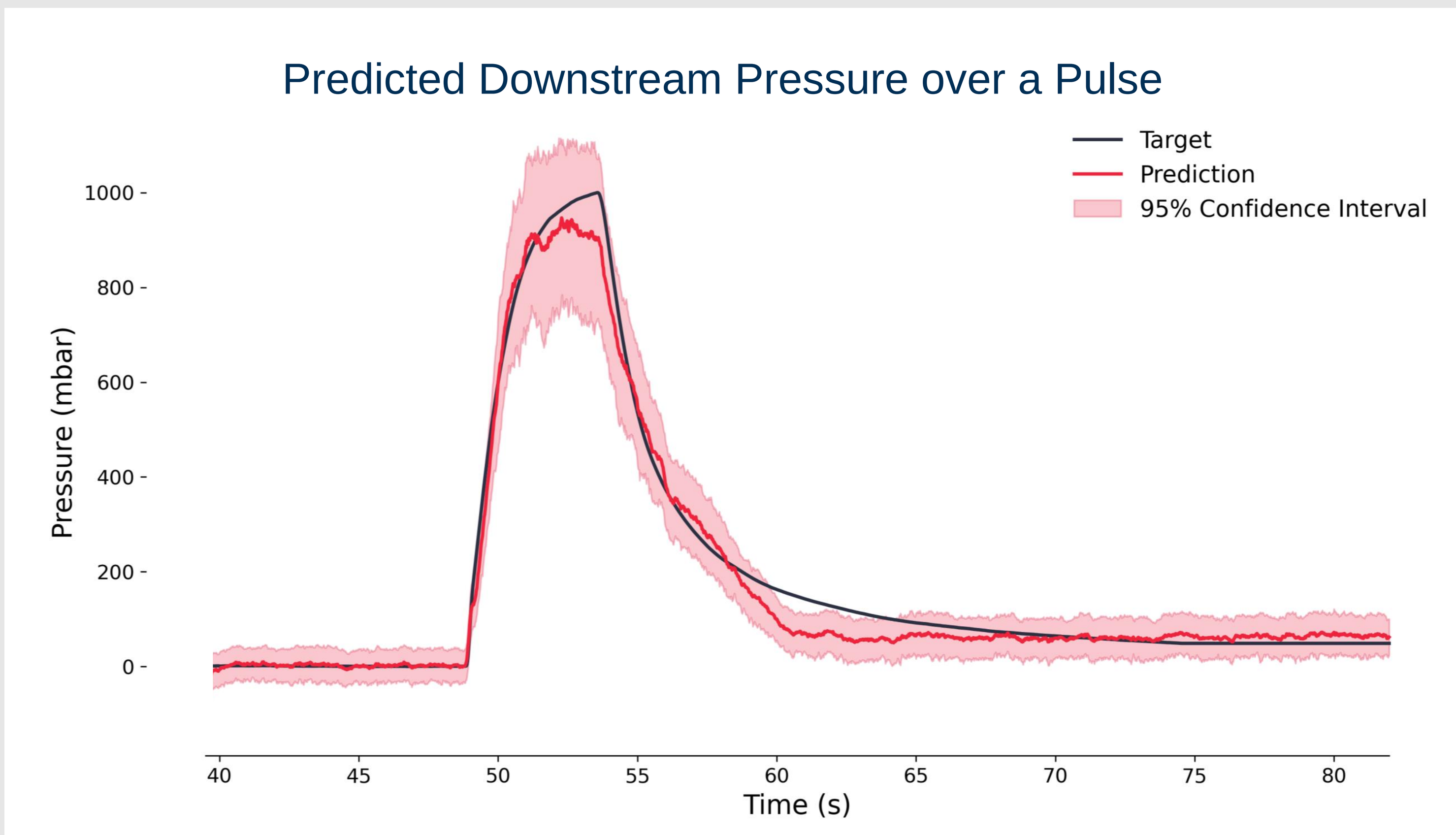
A plant simulator was developed to demonstrate controller performance before deploying.
The controller provides valve actuator commands, and the simulator returns pressure values.



Plant Simulator

A Long Short-Term Memory model is better able to learn the time-varying parameter, that is related to the hysteresis of the piezo actuator in the valve, where system identification and Gaussian process models struggle.

4 LSTM MODEL



Recursive LSTM predictions with uncertainty bounds

Trained on historic JET pulse data.
Prediction uncertainty quantified with Monte Carlo dropout.
Hyperparameter values selected with Bayesian optimisation.

5 OUTCOME

- Reduce the number of pulses required to calibrate a controller and lower costs.
- Further experiment repeatability by accounting for TVP.
- Quantifying the risk of controller deployments.
- Potential to produce a predictive controller by integrating the LSTM with an ODE model to apply physics constraints.

EUROfusion

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