Enabling Integrated AI Control on DIII-D: A Control System Design with State-of-the-art Experiments

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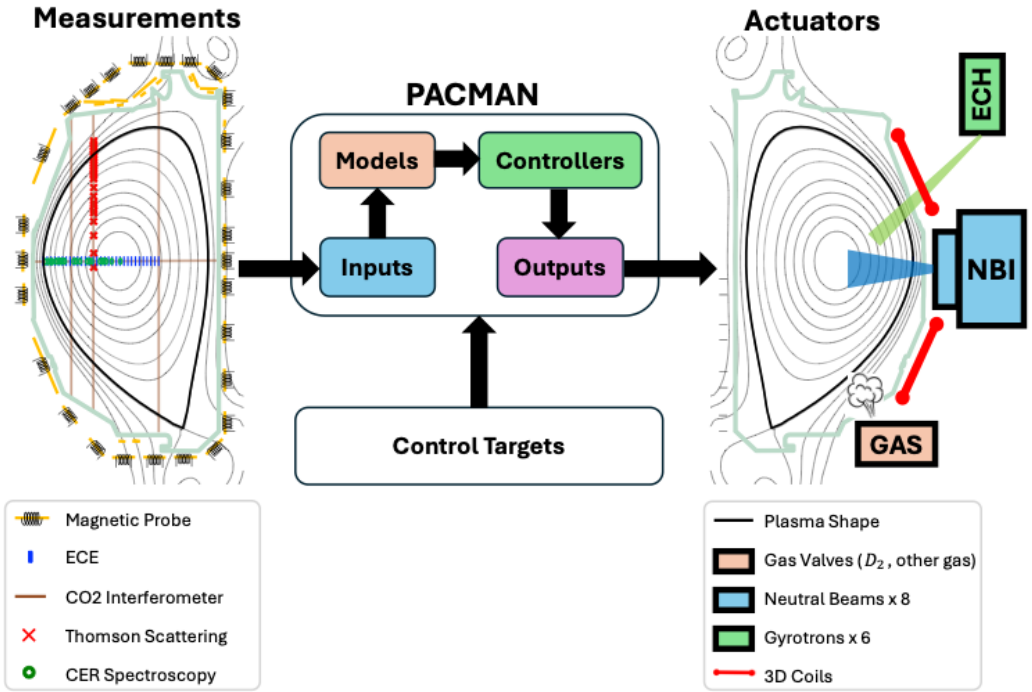
Mechanical & Aerospace Engineering

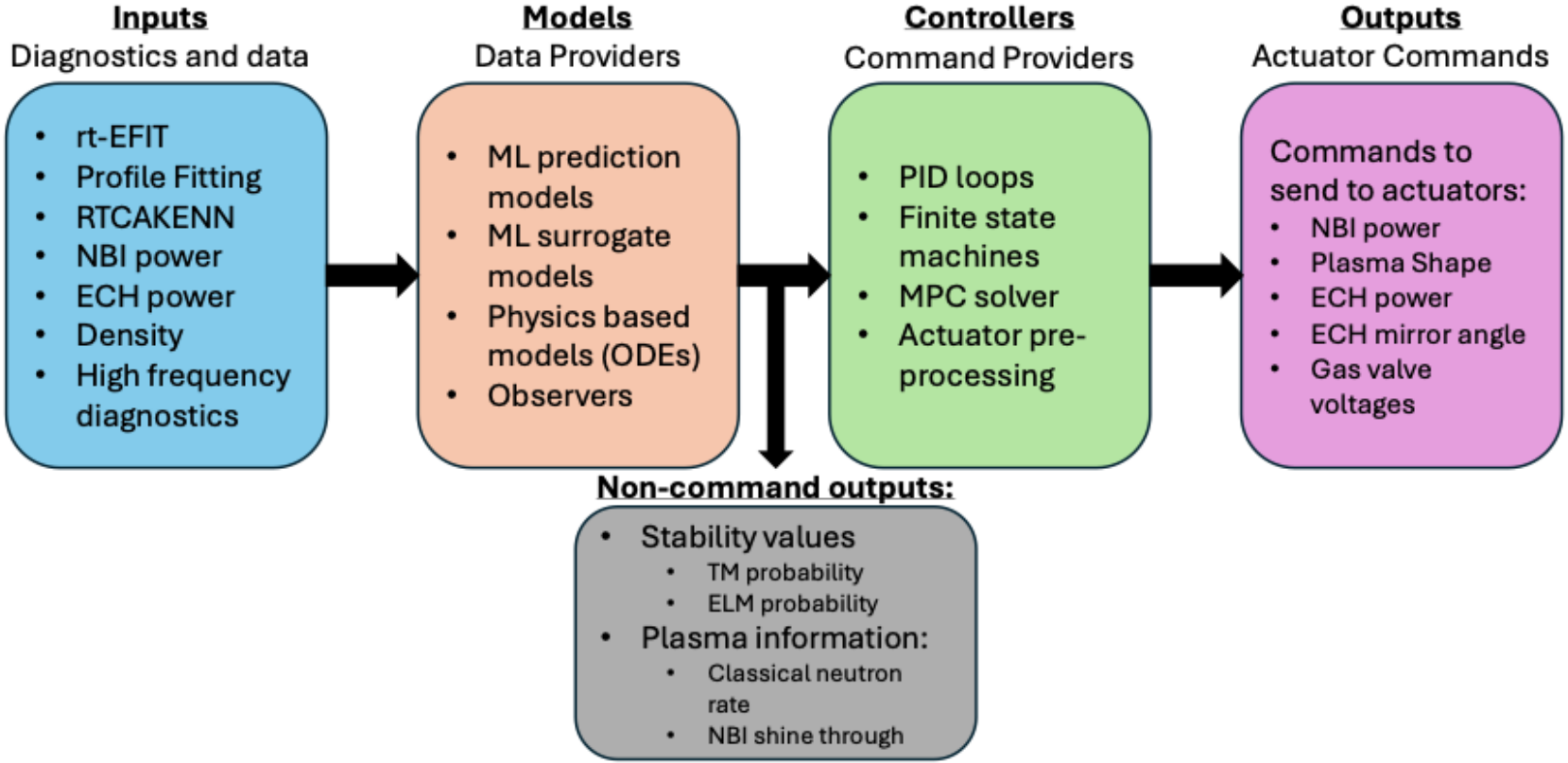
Plasma Control

An integrated framework for advanced control experiments

The Prediction And Control using MachiNe learning (**PACMAN**) framework brings together real-time diagnostics and real-time actuators into one PCS category

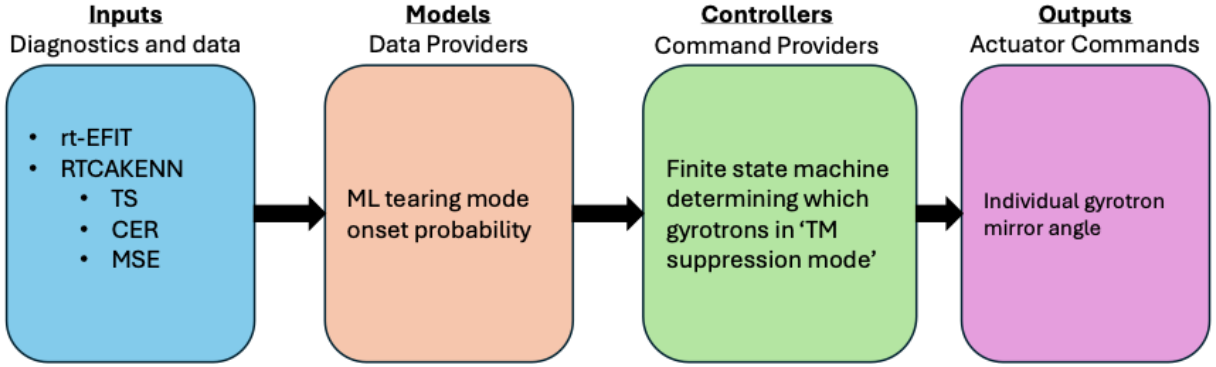


PACMAN creates clear separation of roles with individual blocks

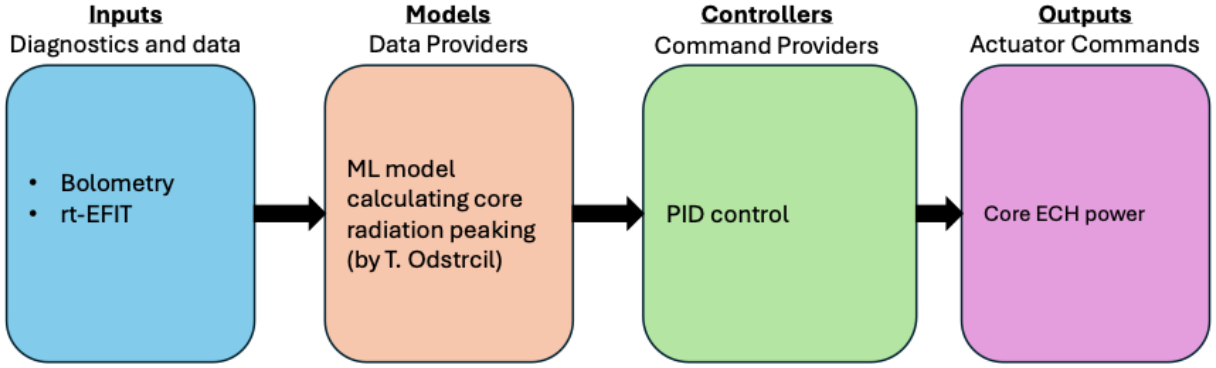


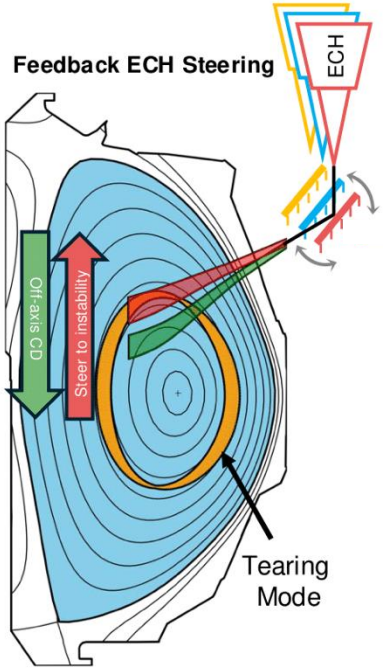
Examples using the PACMAN Framework

- **Tearing Mode Controller**



- **Impurity Controller**





End notes

- PACMAN is a PCS category on DIII-D enabling advanced control experiments
- This has supported five experiments
  - High-qmin reinforcement learning control
  - Tearing Mode avoidance
  - ELM prediction
  - Alfven Eigenmode control
  - Rotation and Density profile multi-actuator control
- It is always growing to support new advanced control experiments
- For more information, please read our paper manuscript:

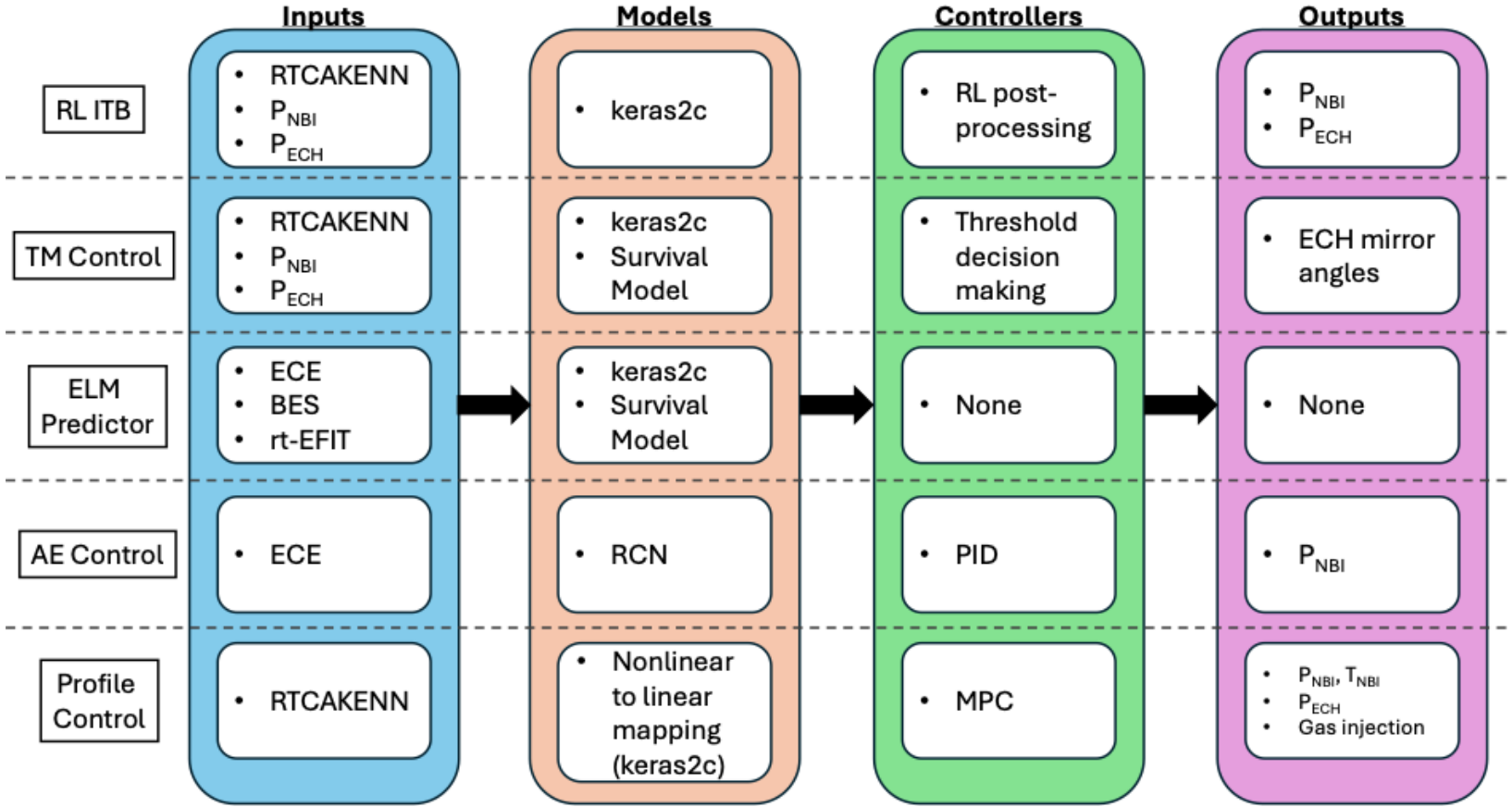
  Enabling Integrated AI Control on DIII-D: A Control System Design with State-of-the-art Experiments, arXiv:2511.08818

Plasma Control

Extra Slide

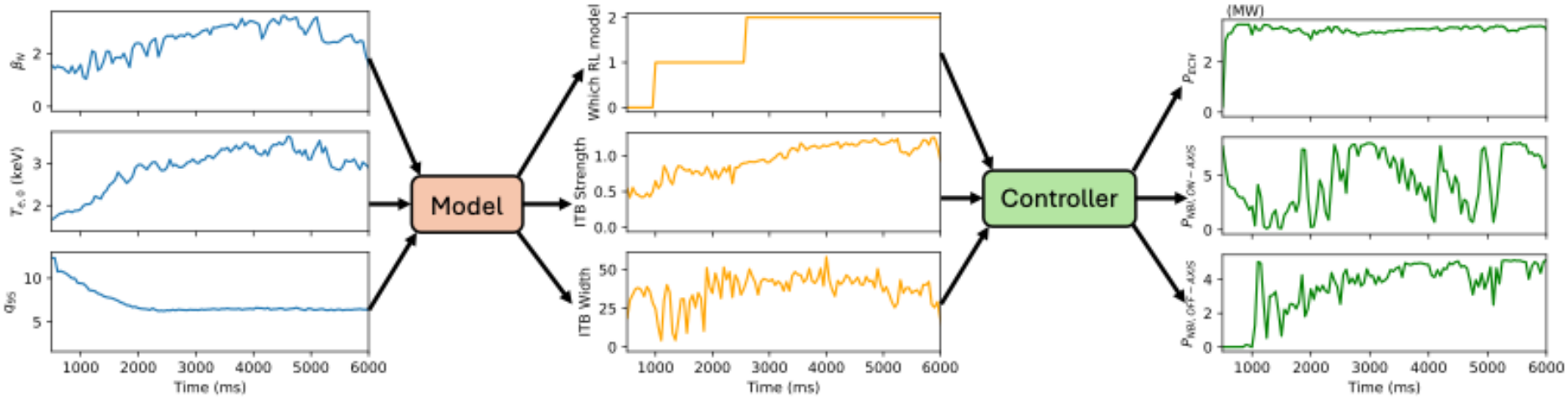
Plasma Control

Current layout of example applications following PACMAN structure



RL control experiment time traces

- A reinforcement learning (RL) controller was deployed in PACMAN
  1. Reads input profiles
  2. Predicts state of Internal Transport Barrier (ITB)
  3. Decides control action to take to match target β_N



3 level design structure of PCS algorithms

- Low Level = closer to diagnostics and actuators
  - Raw diagnostic processing (ex. fitting CER spectra)
  - Sending gas/NBI voltages
- High Level = abstract control objectives
  - Profile control targets
  - MHD stability predictions
- Diagnostics flow up as more processing is done
- Controllers flow down to get closer to hardware