A full discharge tokamak flight simulator

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KEY POINTS:
- Discharge preparation and prediction useful to improve pulse reliability (crucial @ ITER)
- Use as input only Pulse Schedule (no pre-existent experimental data needed)
- Kinetic and magnetic control as in the real-life tokamak plasma
- Reduced physics models from 0D to 2D equilibrium to perform fast simulations
- Use state-of-the-art codes and control framework

Flight simulator Fenix @ IPP

- First ever fully pulse-schedule based tokamak flight simulator Fenix [1,2] built at IPP for ASDEX Upgrade
- Built incorporating a plasma model (ASTRA-SPIDER transport-equilibrium solver [3,4,5]) into the PCSSP Simulink framework [5]
- PCSSP is the framework chosen for ITER to embed the control system and its modules

Reduced physics models in ASTRA-SPIDER

- Globally:
  * quasi-stationary MHD equilibrium model (Grad-Shafranov equation)

- Locally:
  * Core transport model for Te, Ti, ne, nZ
  * Edge/pedestal models, L-I-H-L-I transition models
  * SOL transport model for exhaust (heat flux) and for particle balance (fueling)
  * SOL/divertor model for exhaust and particle balance
  * Plasma-divertor and plasma-wall interaction models

- The core region, defined from magnetic axis to pedestal top radius, is determined by assigning diffusivities with some models
  * For T_e and T_i:
    - simple gyro-Bohm model scaled to give H = 0.4-0.5 in L-mode, R ~ 1-16 ms
    - T_e ~ 0.6, T_i ~ this is usually observed in standard
  - Ion source and can strongly influence

  partial pressure as a source, pump as a sink

- SOL/divertor model for power. 0D scaling for plate temperature as a function of power entering the SOL at mid-plane
  and impurity content. Can lead to detachment when radiated power exceeds a certain threshold. Not yet tested!

- Heating models:
  * HEARTH [M. Weiland et al 2010 Nucl. Fusion 50 063011] for NBI
  * NBI power model for ITER

- Fueling models:
  * Simple Kadomtsev-based sawtooth model
  * Electron density follows from quasi-neutrality. Solve for deuterium/tritium and impurity particle transport in the core
    - Negative triangularity discharge #36026
    - Ramp-up / entry into burn phase also simulated

References

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