The MAST Upgrade Plasma Control System

Graham McArdle, Luigi Pangione, Martin Kochan

Culham Centre for Fusion Energy, Culham Science Centre, Abingdon, OX14 3DB, UK

UK Atomic Energy Authority

ID: 516

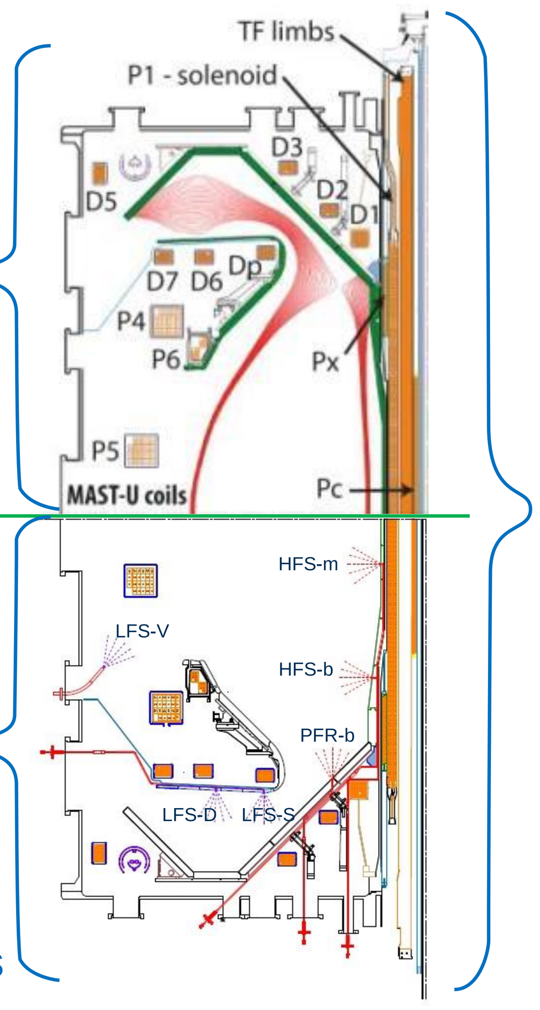
Introduction

The plasma control system (PCS) for MAST Upgrade inherits most of the original MAST hardware / software architecture, which was based on an architecture developed by General Atomics. Whilst the digital control hardware has already had a mid-life upgrade, some additional I/O was required to support the many extra input signals, poloidal field (PF) coils and gas channels on MAST-U. The generic software infrastructure from General Atomics has been retained for MAST-U but the tokamak-specific algorithm software has been substantially re-written to support the additional capabilities of MAST-U, especially in the areas of gas injection control and coil current control. The software structure presented here has been designed to provide maximum flexibility to exploit the new features of MAST-U whilst maintaining a manageable degree of complexity in the operation of the system.

The new MAST-U actuators

- 22 PF coils (including solenoid)
- 12 PF power supplies

A different combination of the same coils is needed to control each plasma shape parameter – complex to manage

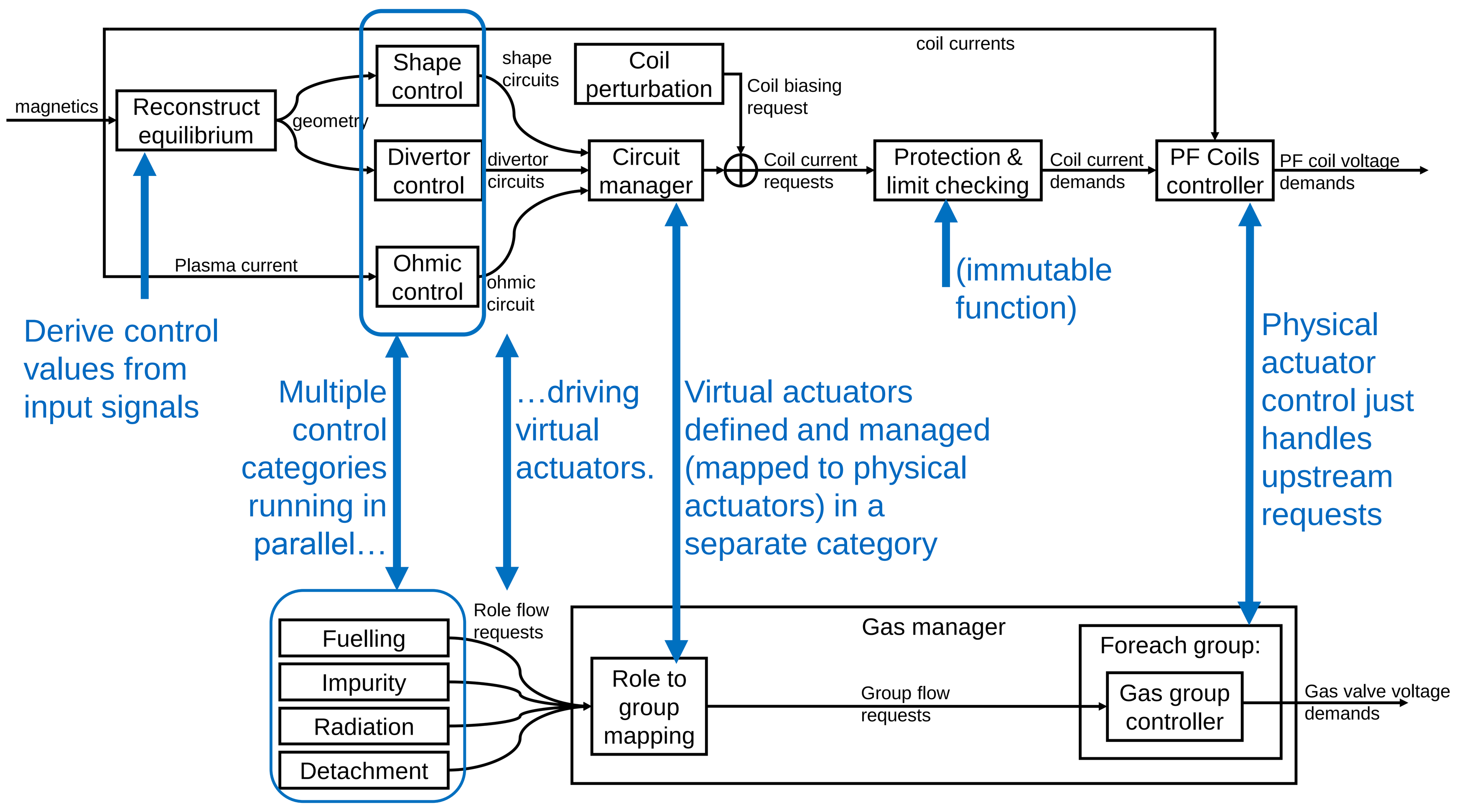


- 6 separate gas plena supplying
- 11 toroidally symmetric groups of
- 48 individually calibrated valves

Need to do multiple simultaneous gas control tasks, any gas group can be assigned any control task. Any plenum may contain any of several gas choices

Common Concern: Many actuators need to be used simultaneously in multiple control tasks.

Function flow for PF coil & gas control



PCS software architecture

Foundation is the General Atomics PCS framework.

- The "category" is at the top of the hierarchy. Time segments are per category

category	pulse duration			
System	(Single immutable function and global data)			
PF control	pre-magnetise	breakdown	ramp-up	flat-top
Gas control	inactive	prefill	density control	density + XYZ
Category X	inactive	function A	function B	function A

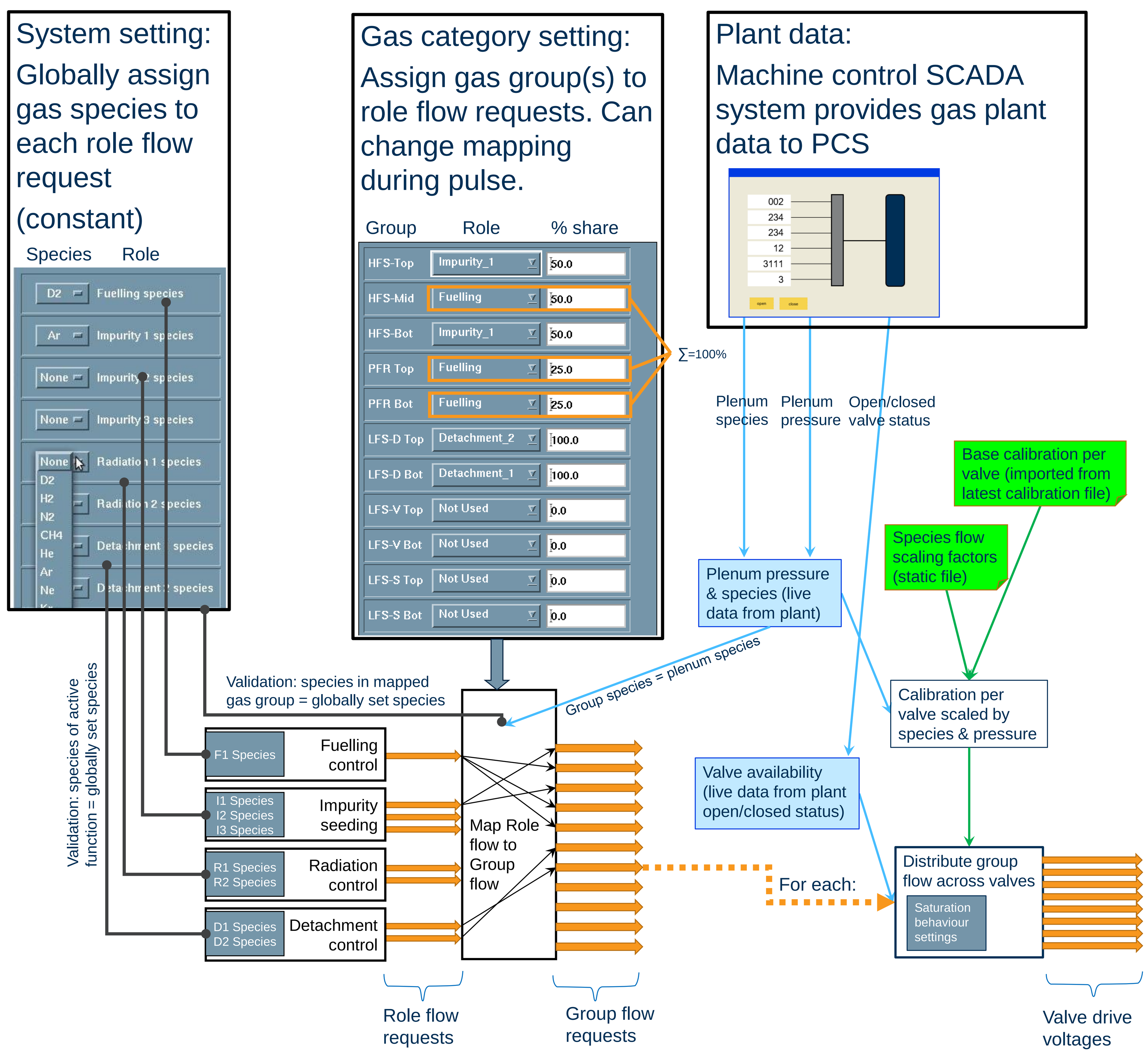
- Each category (gas, PF, etc.) is a placeholder for execution of interchangeable functions
- What executes in a category can be switched independently of other categories
- Only the active function executes (or exists). Concurrent execution = multiple categories

- Need to ensure consistency when data producers or consumers are switched.
- Data has global read / write access – each data item should be owned and written by only one category to avoid conflict.

Architecture decisions for MAST-U PCS:

- **Specific categories 'own' actuators.** Ensures no conflicting commands to plant.
- **Define a functional chain of categories for each of PF coil and gas control:**
  - Breaks the complexity down into separate simpler stages offering layered, flexible control
  - Each stage can be implemented by an extensible choice of independently switchable functions
  - Final stage actuator management is oblivious to the origin of plant drive requests
- Define a consistent data exchange between categories in the chain
- Define multiple parallel controllers, each driving different sets of **virtual actuators**
- Separate categories **map virtual to physical actuator** commands
- The virtual actuator mapping and the controllers can each change independently

Detail of gas control implementation



Implementation for PF coil and gas control

- Virtual actuators for PF coils are "virtual circuit currents":
  - Each defined by a vector of physical coil currents with set proportions
  - The combination of coil currents uniquely controls one plasma parameter of interest
  - Defined by control experts, made available for selection by Session Leader
  - Control actions are 'delta' requests to change current only. No mapping to absolute currents
- Consistent coil control protection maintained regardless of active upstream controller
- Virtual actuators for gas are "role flow requests".
  - Each gas group can only be assigned to one role
  - A role can be shared across multiple gas groups with defined sharing ratio (see later)

Summary/Conclusion

We presented the architectural design for the MAST-U PCS, implemented on the General Atomics PCS framework

- We dealt with the presence of many actuators for coil and gas control, and the need to change controller behaviour in multiple ways during a pulse
- We managed these challenges by chaining together PCS categories and the use of "virtual actuators" to aggregate/arbitrate/route multiple upstream controller demands to finite downstream actuator commands
- In doing so we achieved a powerful configuration capability while managing underlying complexity and ensuring consistency-checking against configuration errors
- We created a framework that can stay abreast of the evolution of the MAST-U plant

CCFE CULHAM CENTRE FOR FUSION ENERGY

EUROfusion

This work was part funded by the RCUK Energy Programme [grant number EP/P012450/1]. This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-20 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Contact: graham.mcardle@ukaea.uk