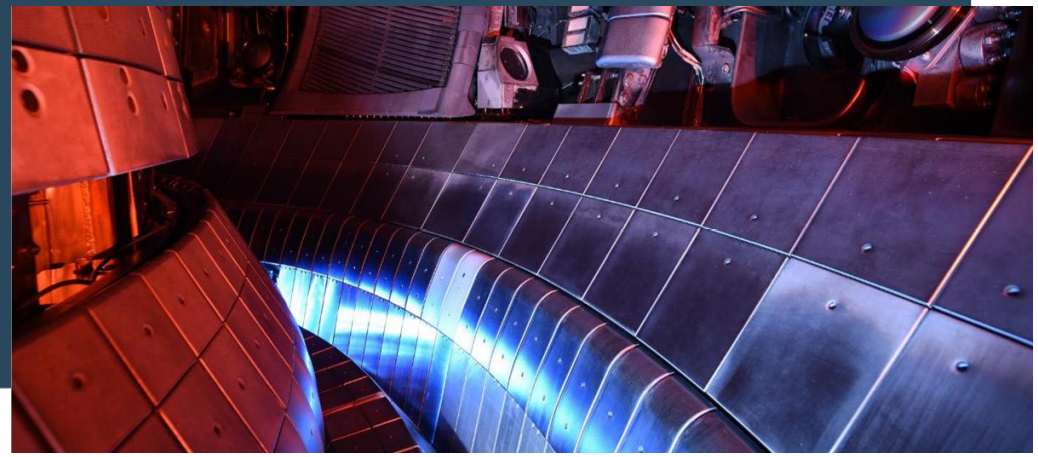
Development of a flight-simulator coupling ASDEX Upgrade control system to ASTRA

Marco Biasizzo

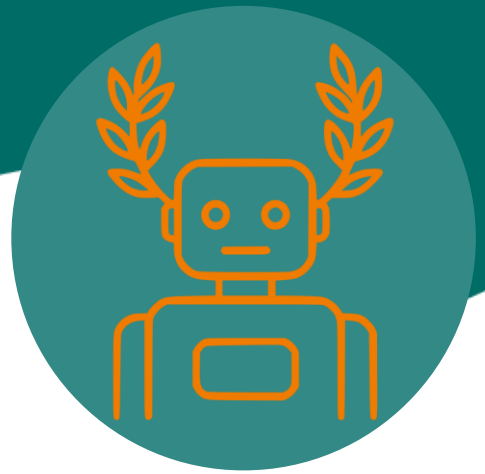
↘ ***HEPP Introductory Talk, 7th July 2025***

Supervisors: Pierre David, Mariano Ruiz



This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Something about me



Munich

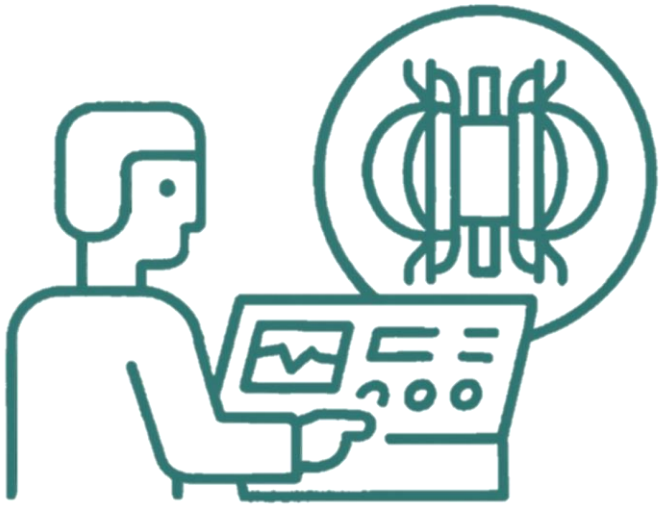
Udine

Milan

Pisa

Marco @ IPP

- **CODAC Control** team
  (**CO**ntrol and **D**ata **AC**quisition)



- PhD student at **UPM**
  (Universidad Politécnica de Madrid)
- In **Information Engineering**

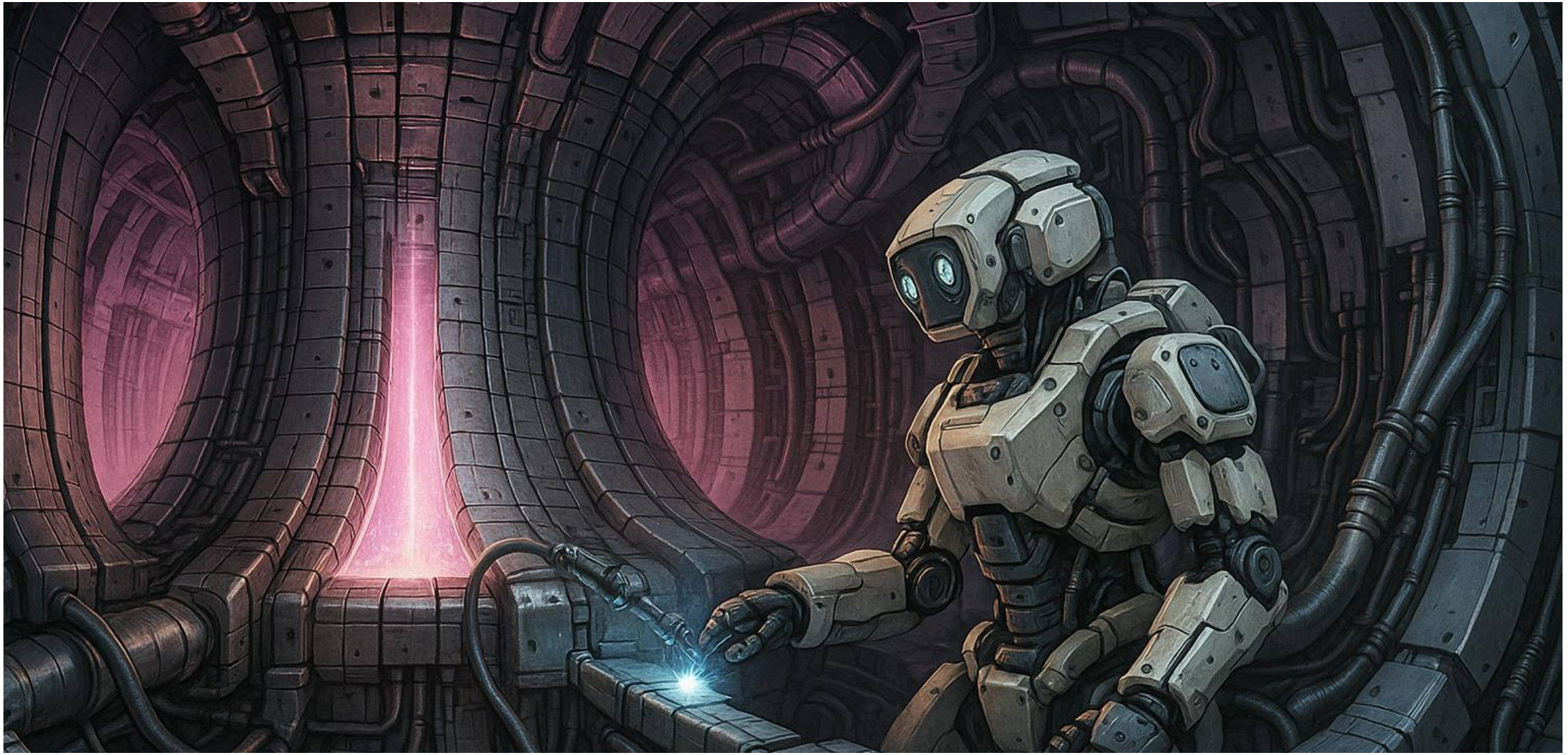
Outline

1) Something about me

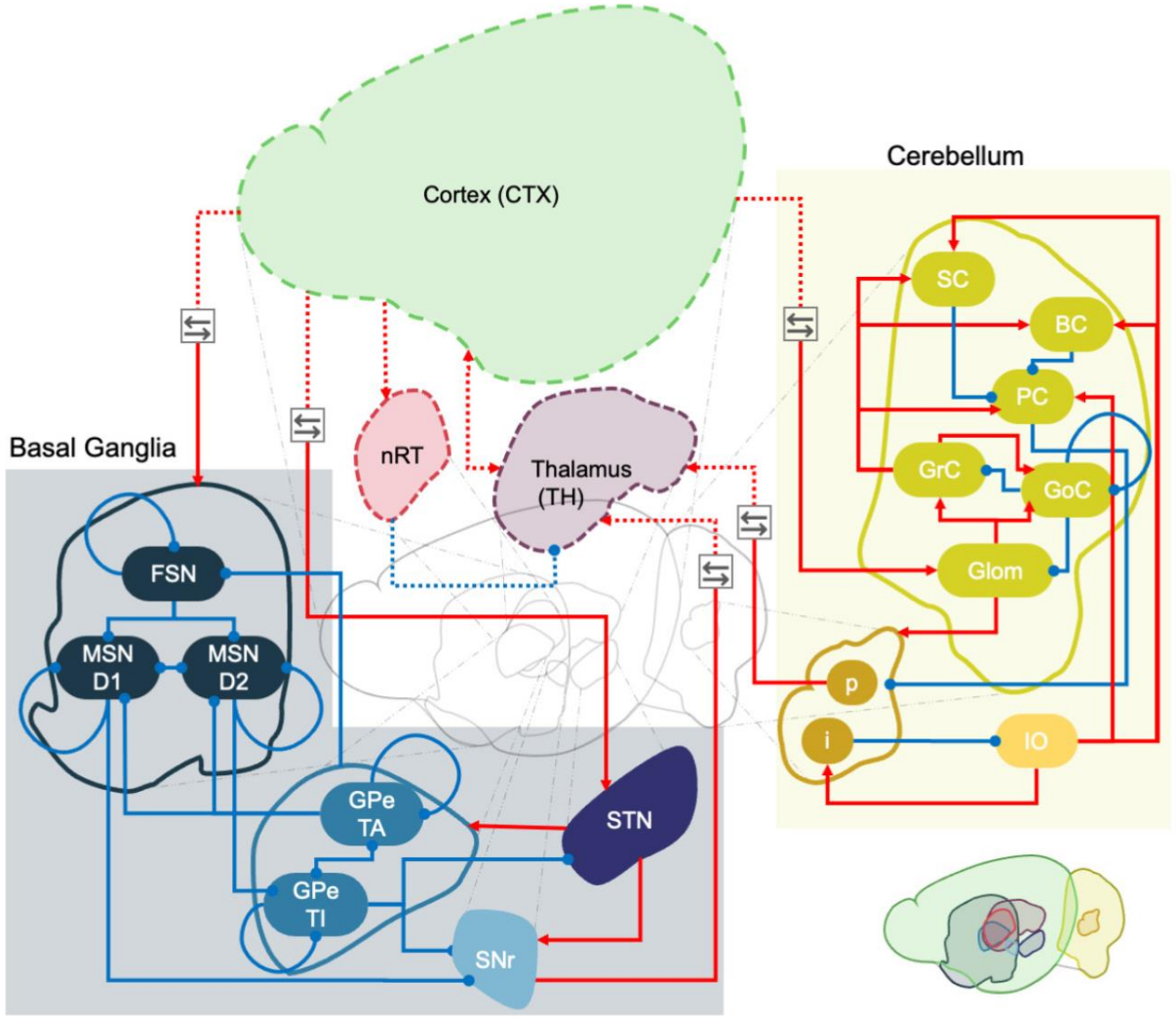
2) Master thesis project

3) Control: what and why?

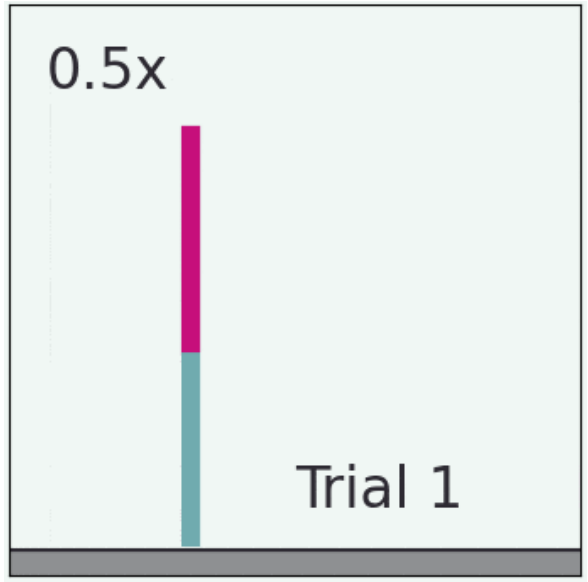
4) AUG flight simulator



Cerebellum as motion controller



- **Integrated model** of mouse motor brain regions
- Applied to **control** a simple movement
- Based on a **reinforcement learning** approach, the cerebellum activity self-adapted to perform the task



Gambosi, Benedetta, et al. "A model with dopamine depletion in basal ganglia and cerebellum predicts changes in thalamocortical beta oscillations." *International Journal of Neural Systems* 34.09 (2024): 2450045.

Outline

1) Something about me

2) Master thesis project

3) Control: what and why?

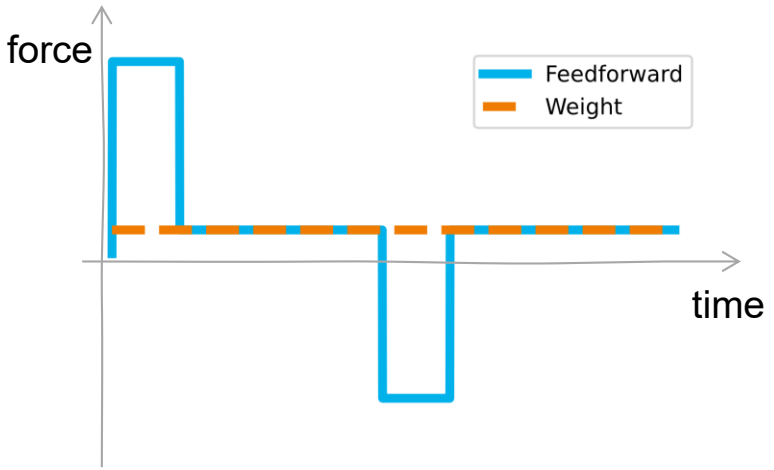
4) AUG flight simulator

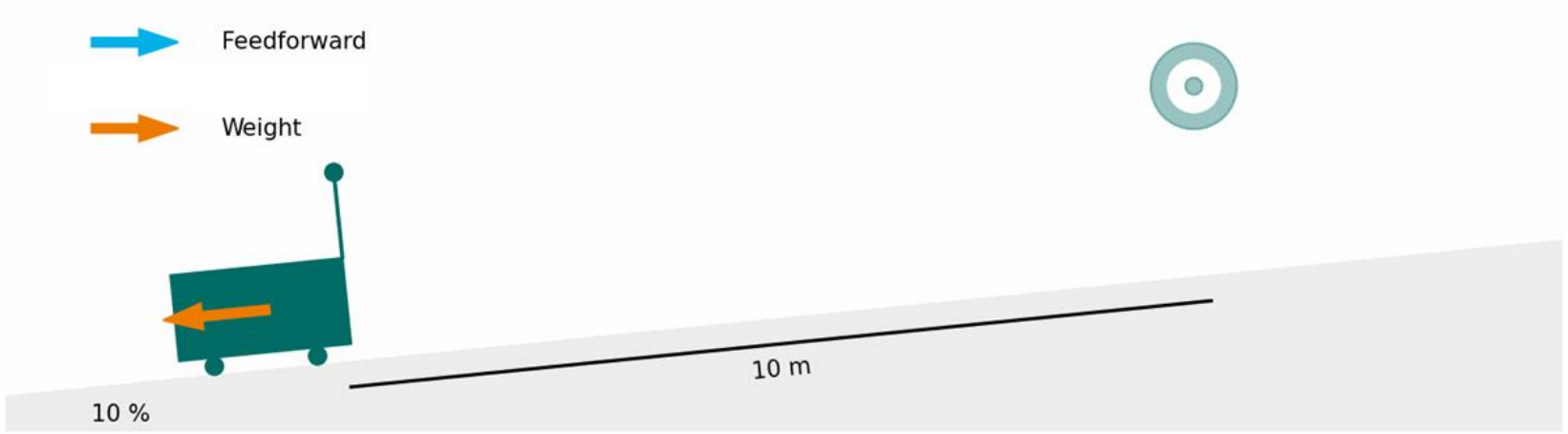
A control example: cart on an inclined plane

Hypotheses:

- Angle of incline: 10 %
- Distance from the goal d = 10 m

→ Find the force **feedforward force** to reach the target

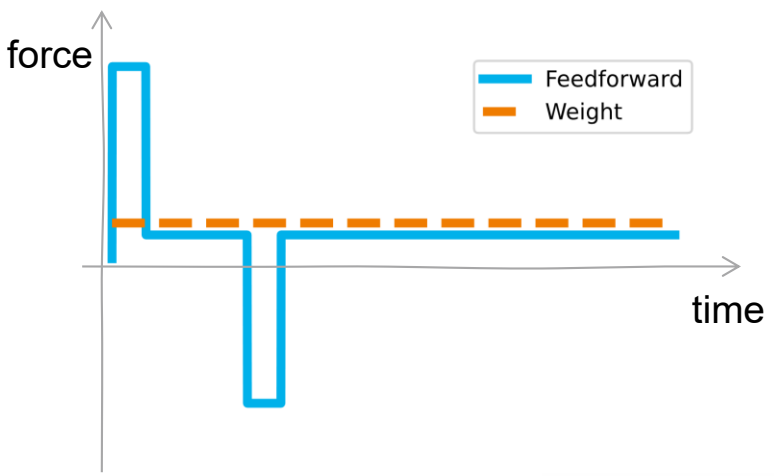


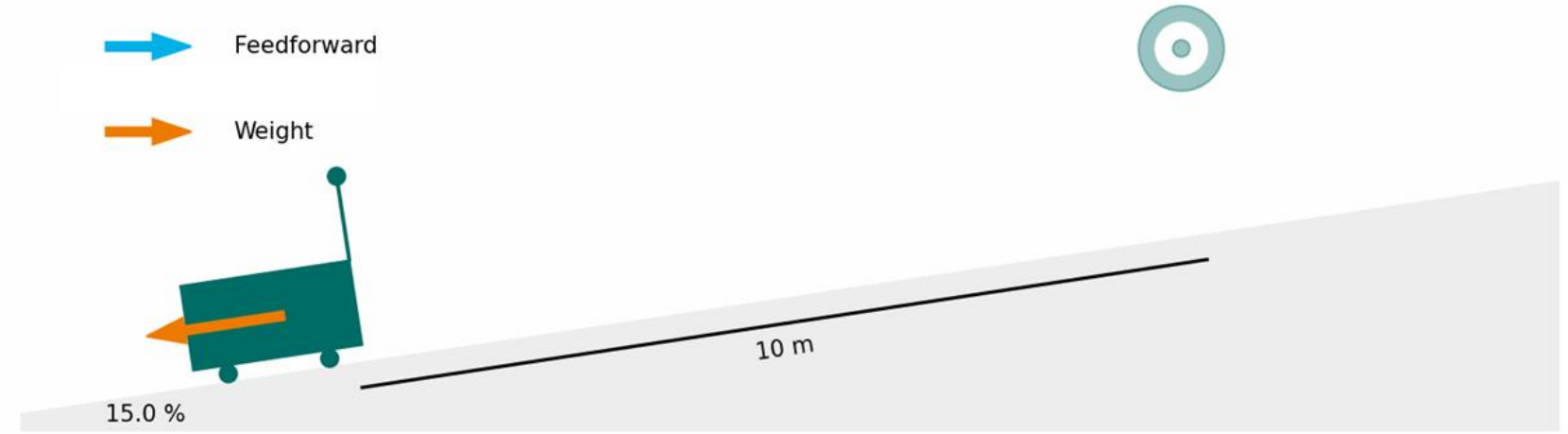


Changing conditions: increased angle of incline

Hypotheses:

- Angle of incline: ~~10 %~~ 15 %, but not known → Cart is lost ☹





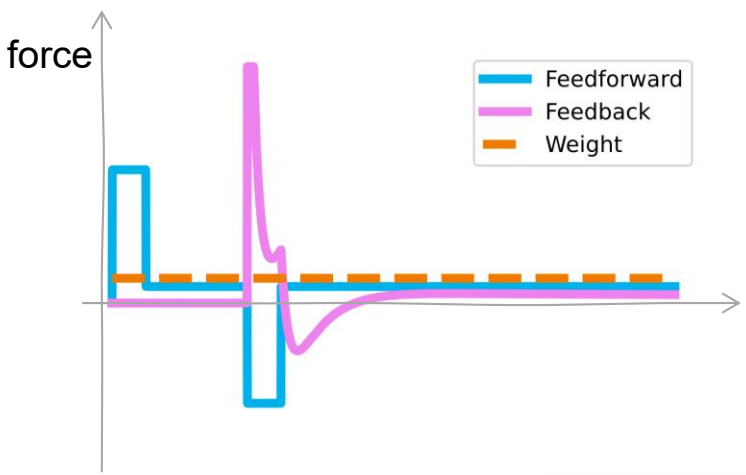
Feedback control : PID controller

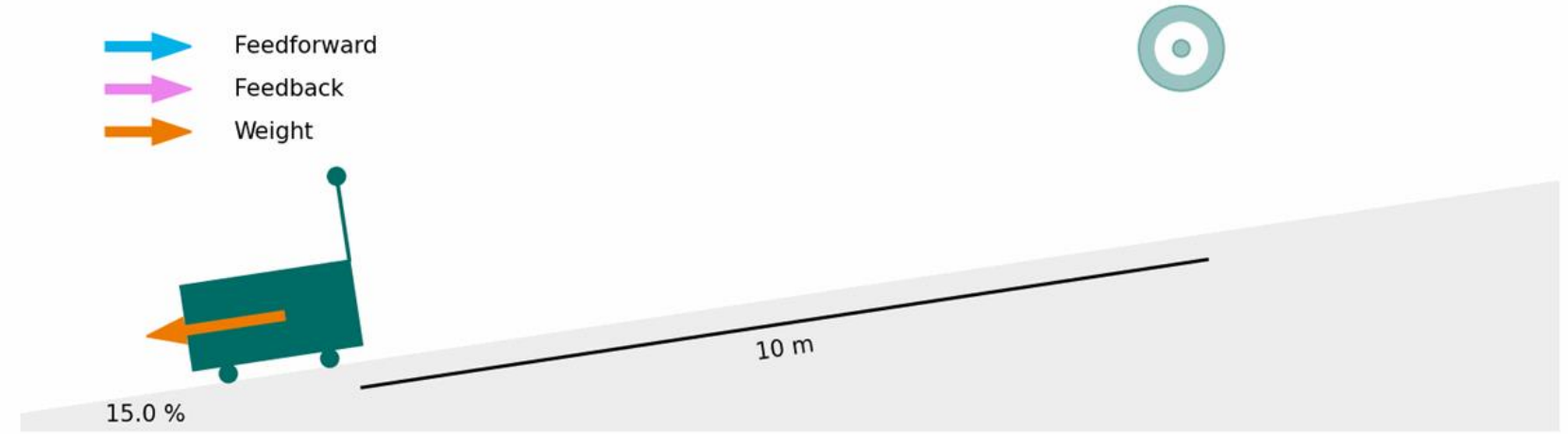
Hypotheses:

- Angle of incline: ~~10 %~~ 15 %, but not known
- Distance from the target is known

→ Apply a **feedback** force dependent on the distance

$$F_{feedback} = k_P e + k_I \int e\,dt + k_D \dot{e}$$

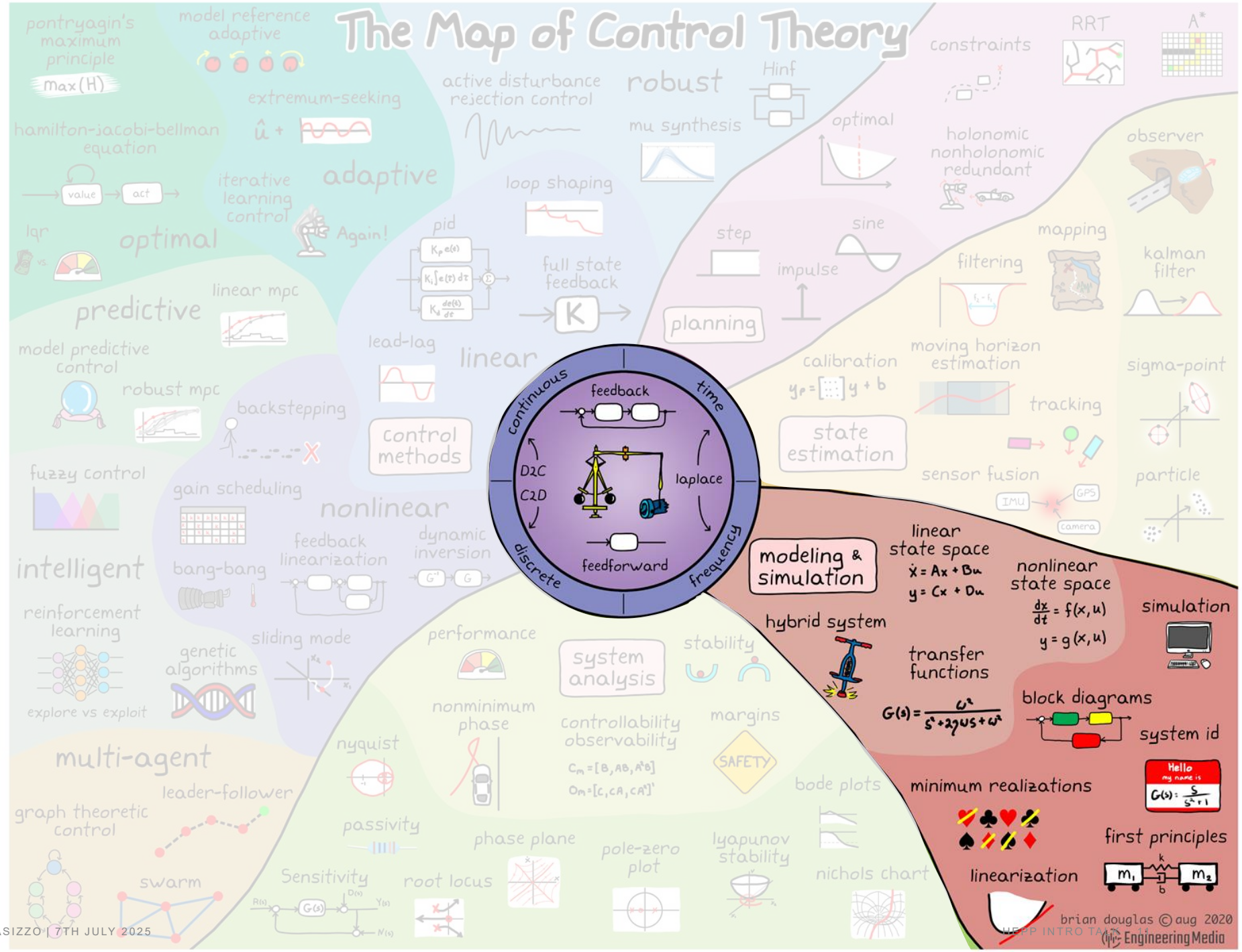




What is control?

Control the behavior of dynamical systems, even in the presence of uncertainties, disturbances, and changing conditions

Importance of modeling and simulation



Outline

1) Something about me

2) Master thesis project

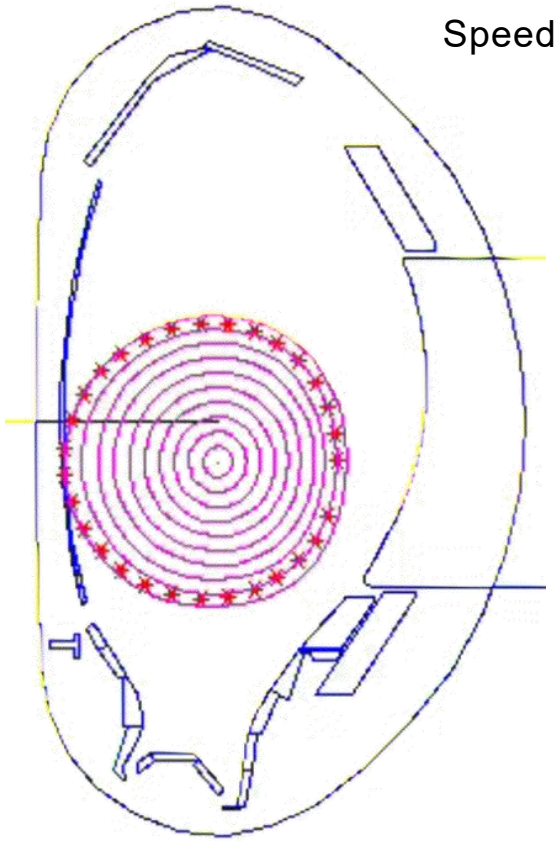
3) Control: what and why?

4) AUG flight simulator

Flight simulators in fusion

- More than just an integrated model
- Includes the **control system**
- Simulate an **entire shot**
  from preparation to termination
  in reasonable time

From the flight simulator

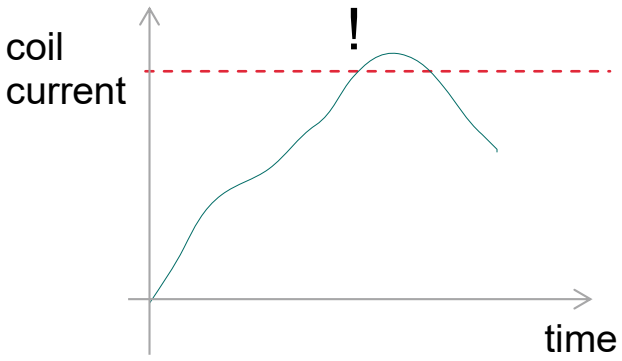


Why a flight simulator?

1

Rough validation of a discharge program before the real shot

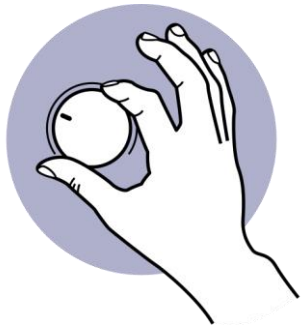
Check for possible limits violation



2

Test bench for the development of new controllers

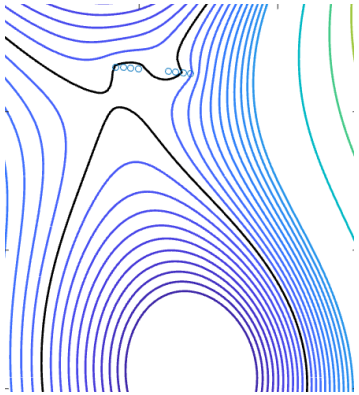
Tune the parameters of a new controller before a real shot



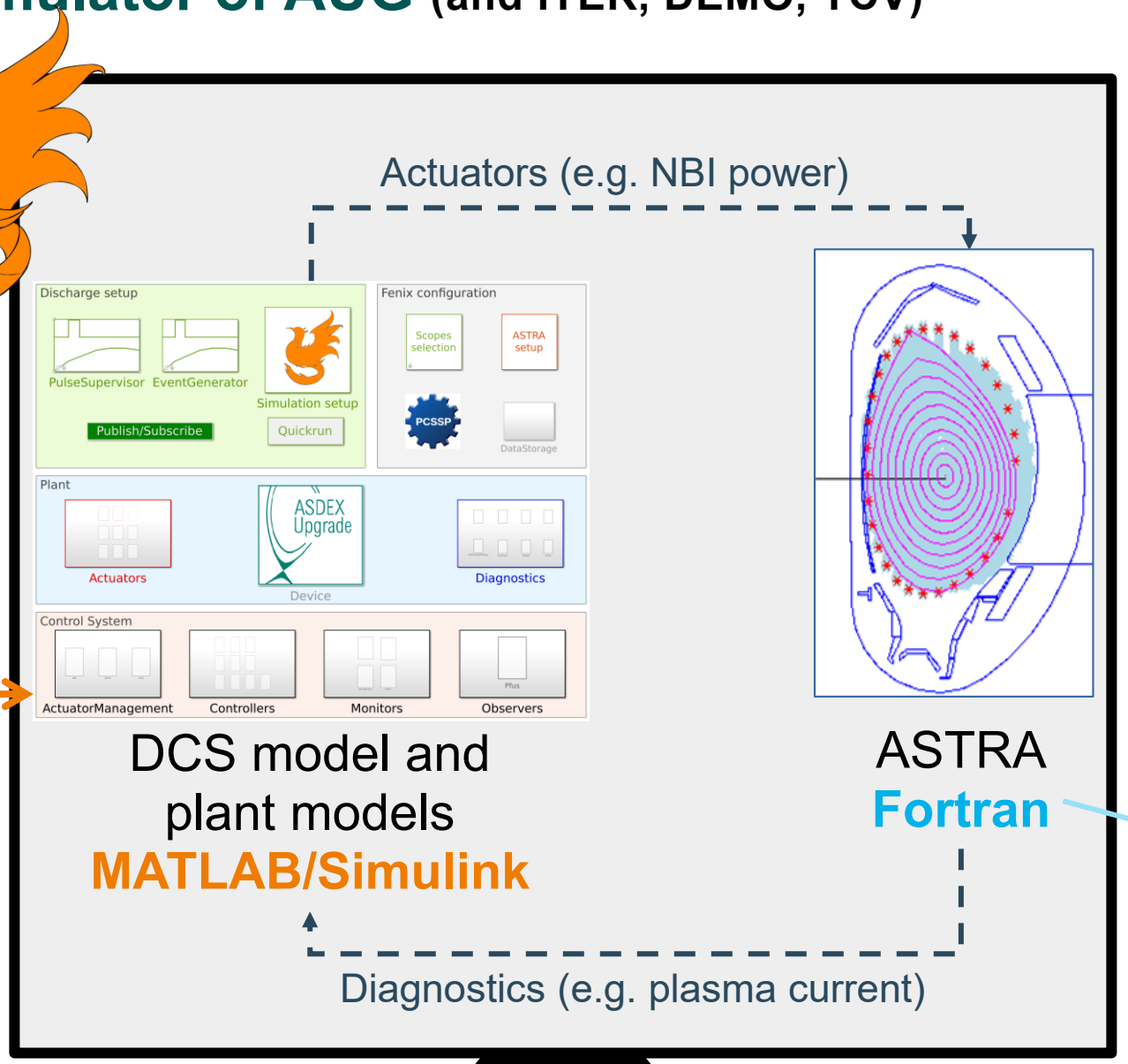
3

Comparison of plasma models to past experiments

Validate a new plasma model against past AUG experiments



Fenix is the flight simulator of AUG (and ITER, DEMO, TCV)



David, Pierre, et al. "Update of the integrated flight simulator for ASDEX Upgrade." *Open Plasma Science* 1.3 (2025).

Before the simulation:

DCS (**D**ischarge **C**ontrol **S**ystem)
C++

- Simple plasma and plant models
- Equilibrium solver
- 1D transport code

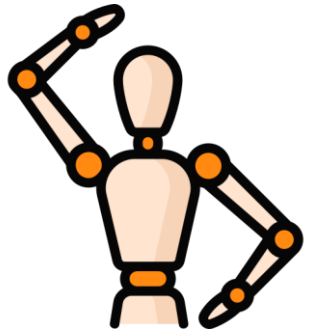
Open points for Fenix

Simulation takes ~10 mins

- **Not possible to run between shots**

Model of the control system

- **Not an ideal copy, may have different behavior**



Possible solution:
Run the real control system code

Code **pre-compilation** and **optimization**

- ~2 mins expected time

Software-in-the-loop

- Copy of the control system

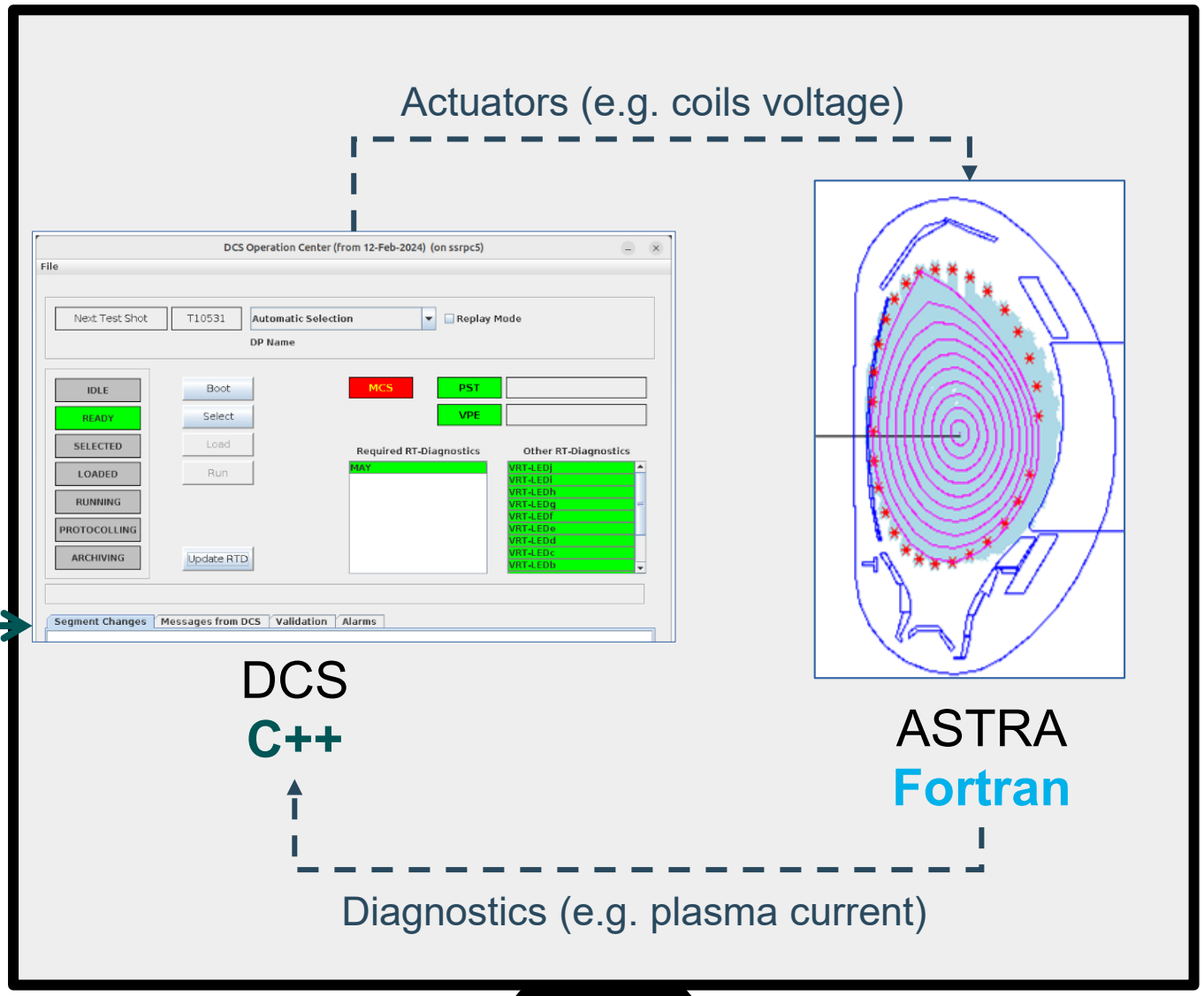
Development of an alternative flight simulator of AUG:

“Fenix-DCS”

Looking for a nice name!

Before the simulation:

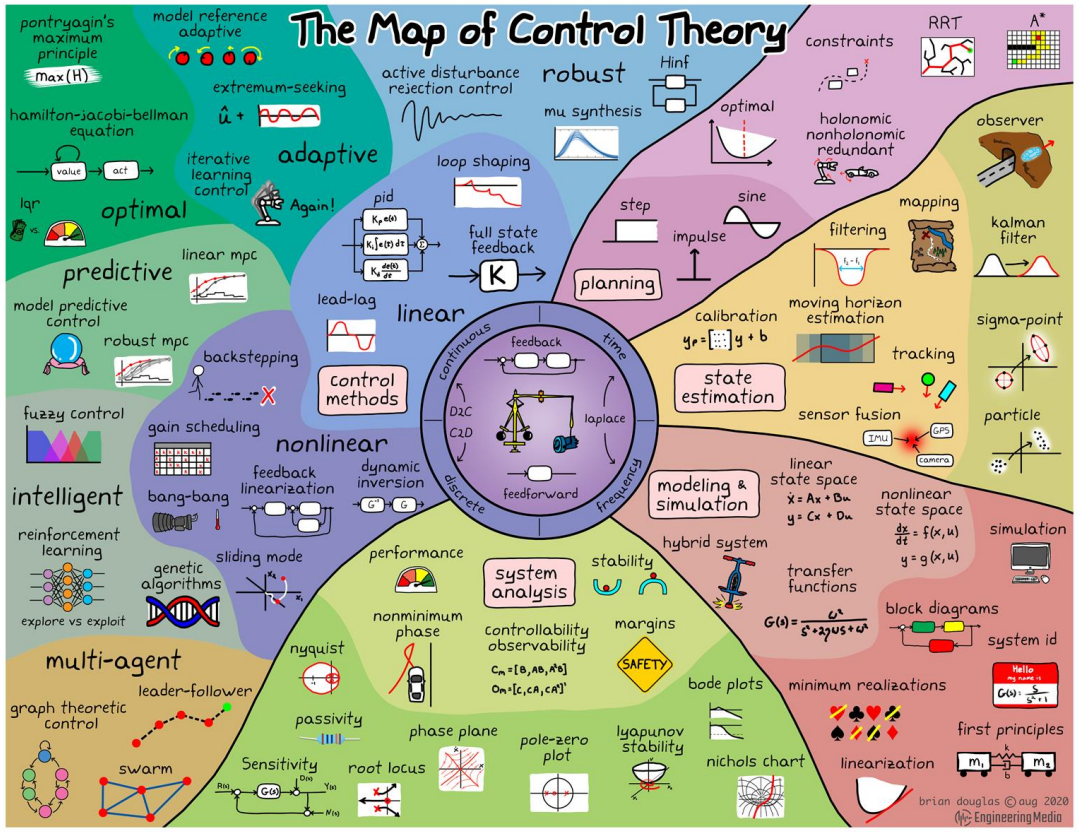
DCS
C++



Future work

- Implement and test the “Fenix-DCS” alternative flight simulator

- Apply “Fenix-DCS” to develop new control algorithms



Thank you!

I would really appreciate your feedback:

ICONS FROM FLATICON.COM