Experimental Framework for Closed-loop Control of Micro-jet Engines

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Educational Project:
“Closed-loop control of micro jet engines”

The project long-term research goal:
to study and test different engine control strategies of the thermodynamic systems.

The project framework objectives:
to develop the experimental testbed providing rapid implementing of the real-time control algorithms

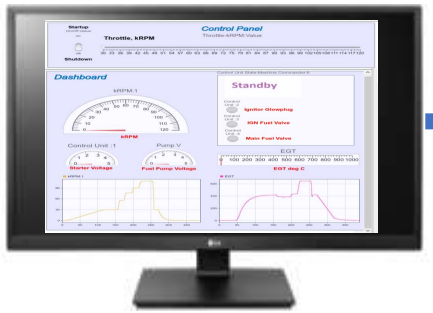
Control Performance Requirements:

- Steady-state error
- Settling time
- Maximum overshoot
- Maximum undershoot
- Minimum Stall Margin

Protection against:

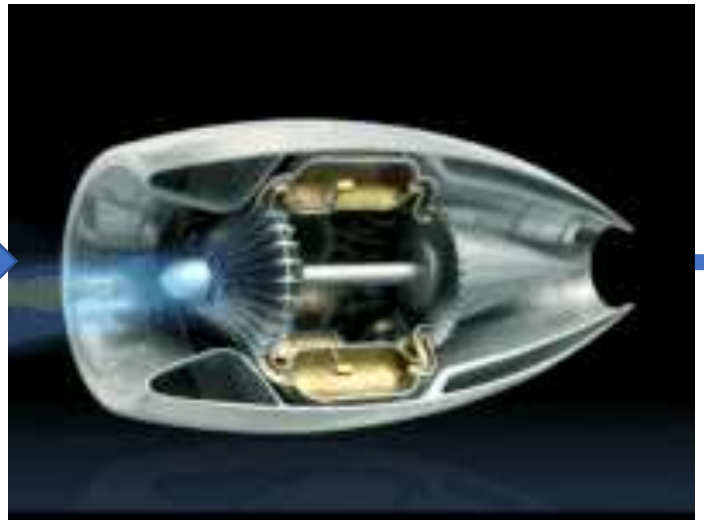
- Maximum Rotational Speed
- Maximum Combustor Outlet Temperature
- Compressor Surge
- Overheating of the Turbine blades
- Rich/ Weak Flameout,

Jet Engine Closed-loop Control



Control Panel
Operator Commands

Electronic Control Unit (ECU)
The company-supplied
AMT Netherlands
built-in microprocessor



Jet engine

RPM
EGT

Feedback

Electronic Control Unit (ECU)

The company-supplied AMT Netherlands ECU built-in microprocessor, which cannot be changed or reprogrammed.

dSPACE Hardware/ Software

Matlab/Simulink/dSpace: a powerful and flexible computing environment for control algorithm design, modeling and analysis

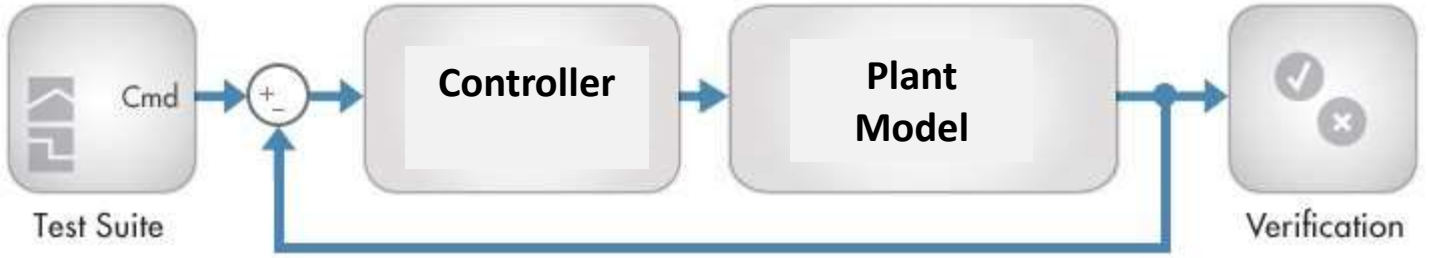
For the project purposes, the original ECU should be replaced with a special designed control unit based on intuitive and flexible software/hardware tools.

From the Simulation to the Implementation

Software in the loop simulation.

Non Real-Time Closed loop System

Matlab
Simulink

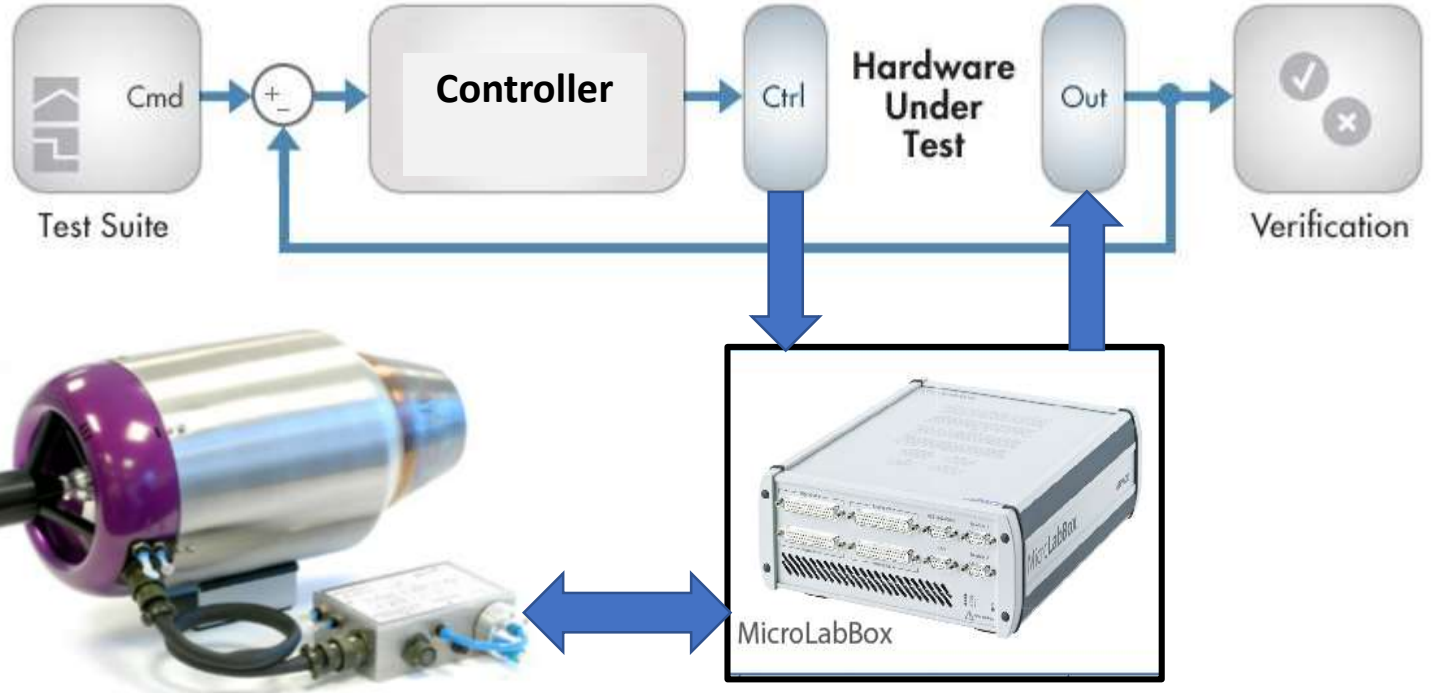


Hardware in the loop simulation.

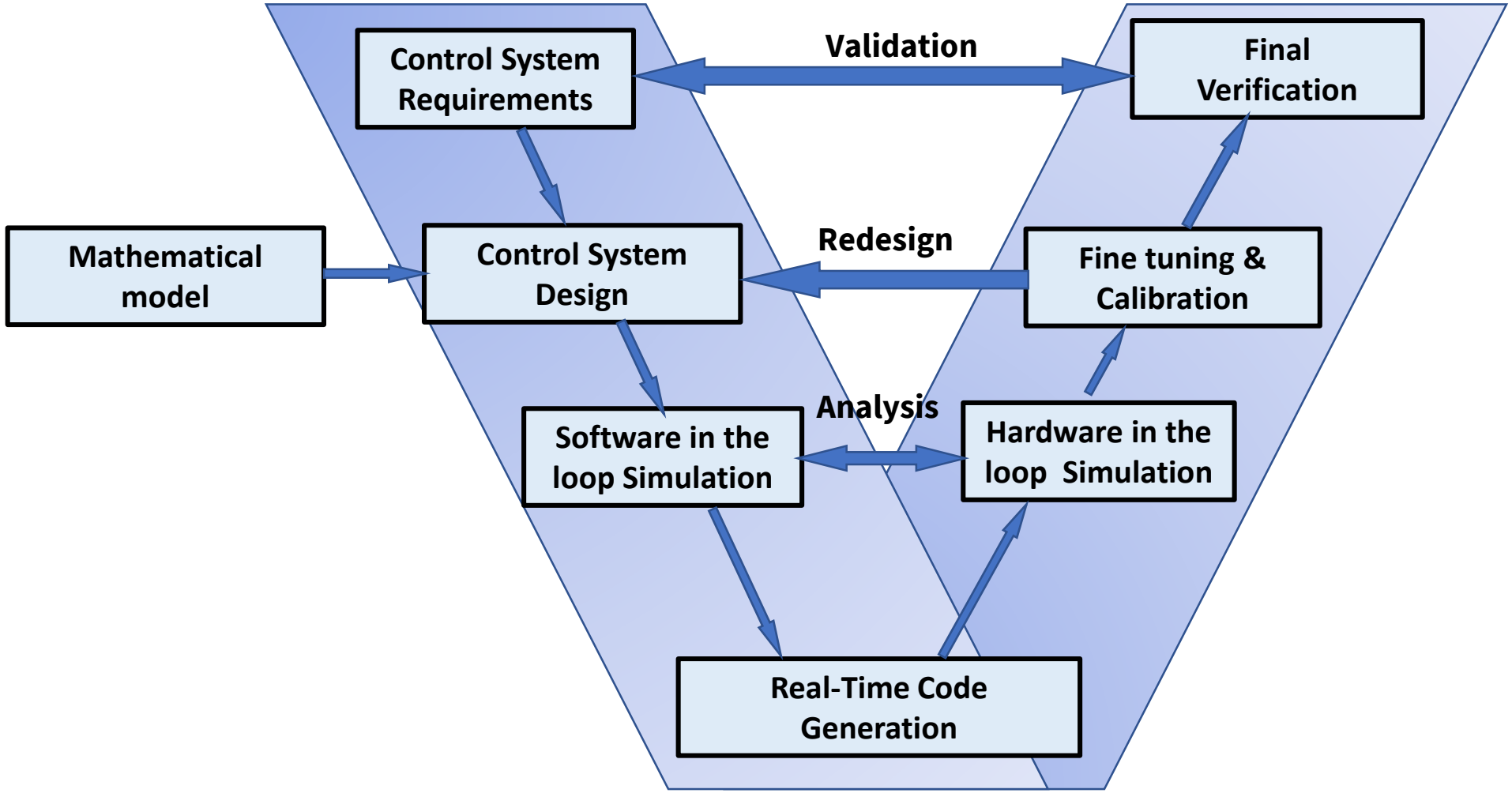
Real-Time Closed loop System

Matlab
Simulink

dSPACE



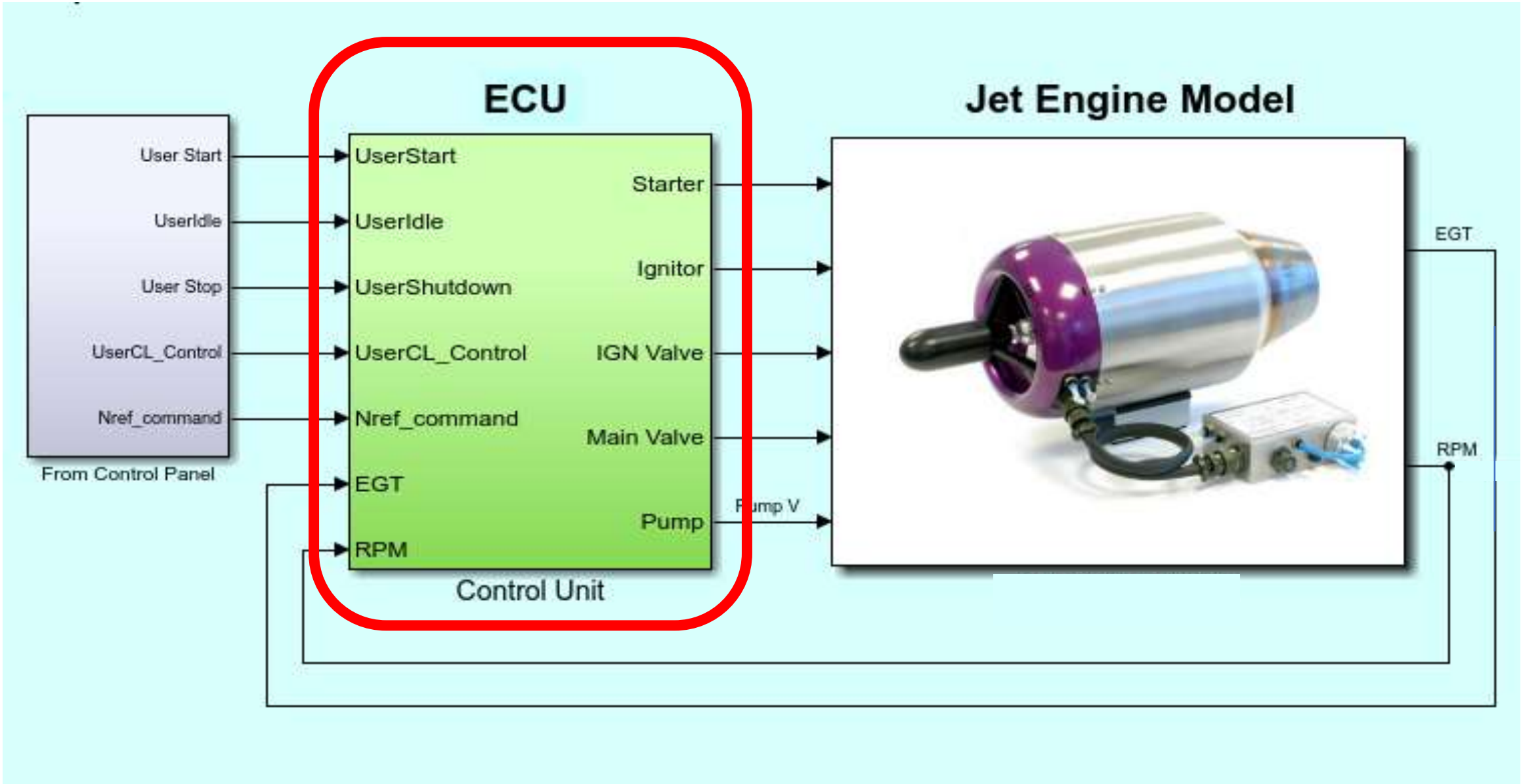
Rapid Control Prototyping Concept



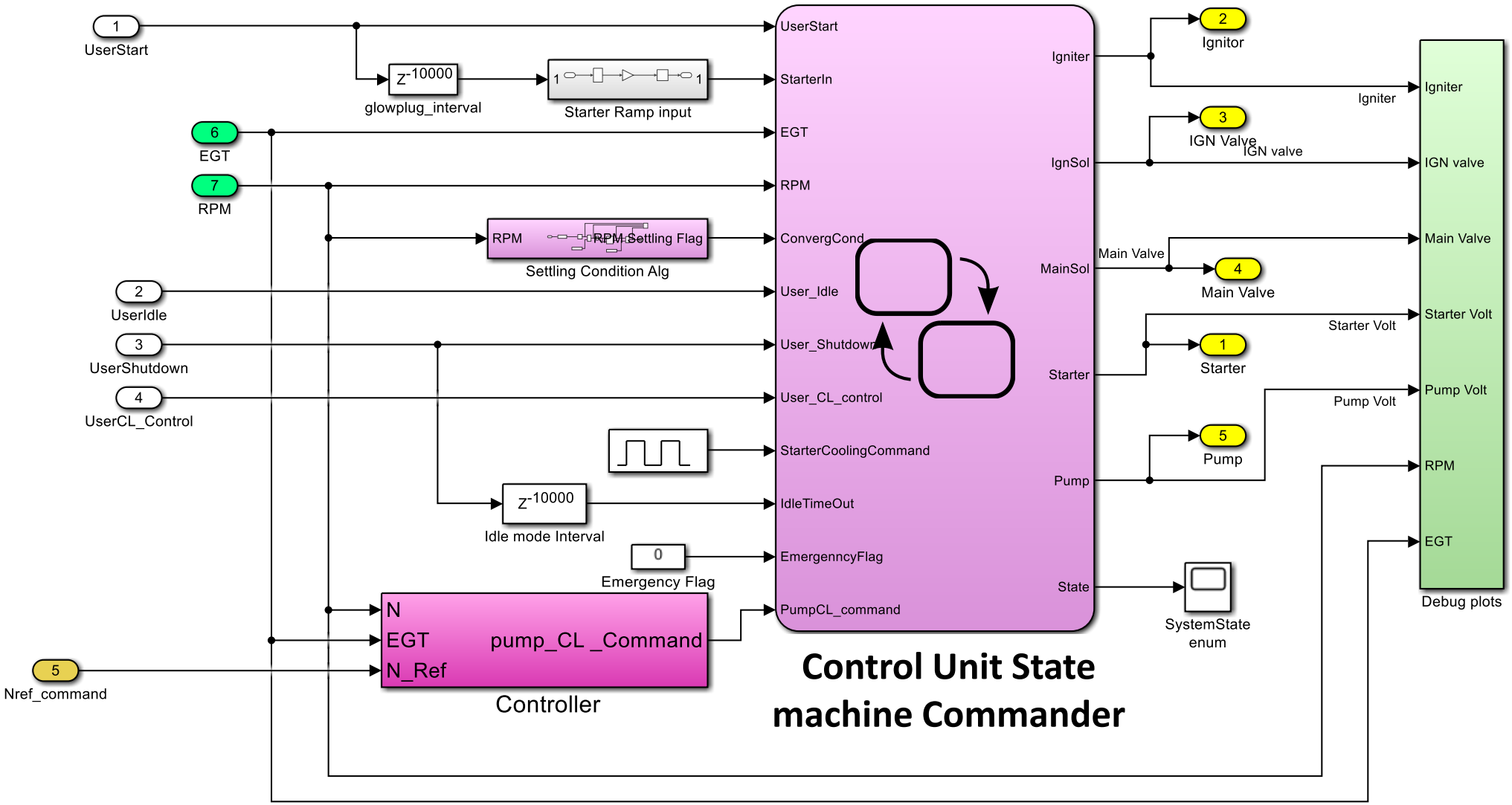
Typical V-cycle for the modern design of control system

Matlab
Simulink

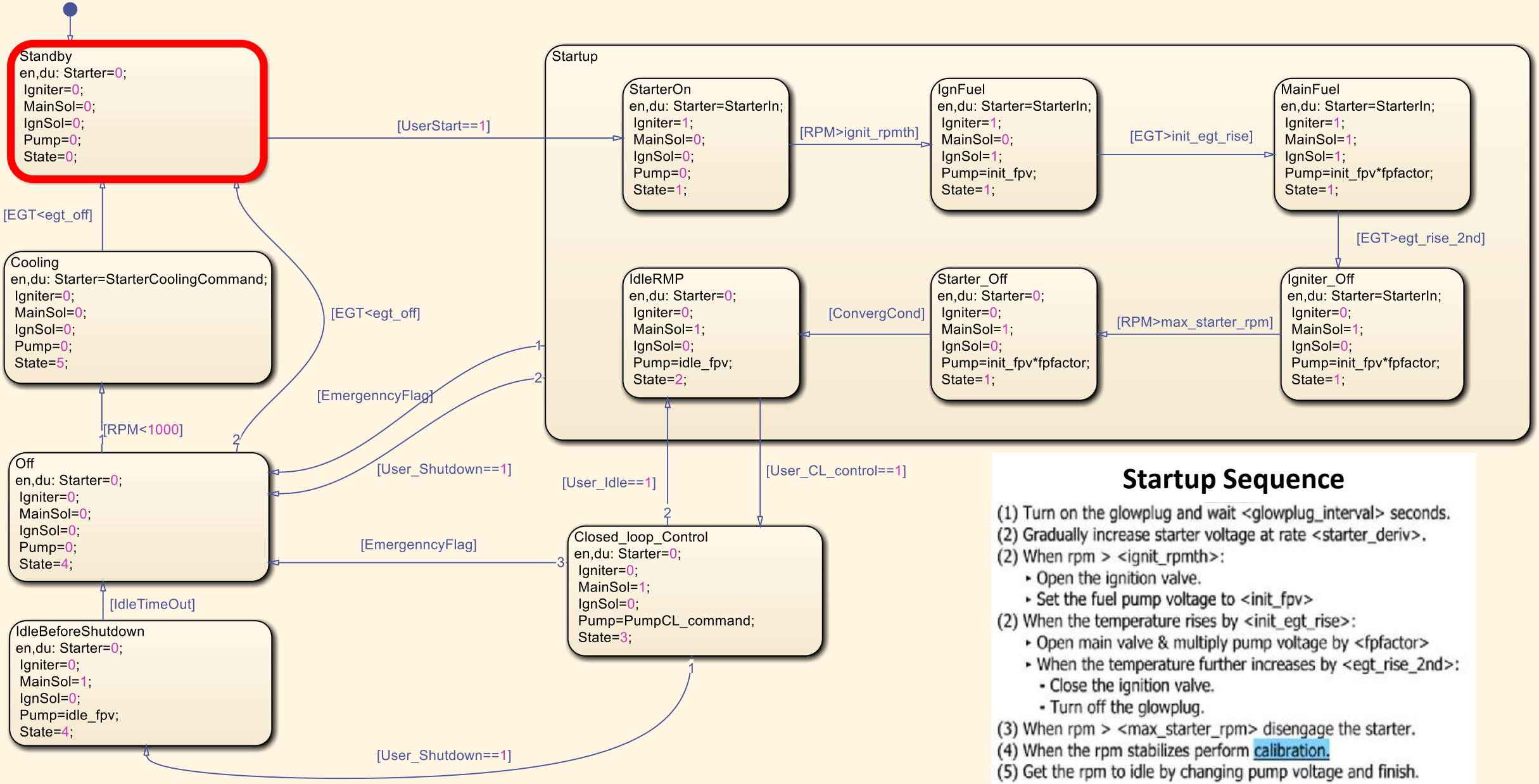
Turbo Jet Engine non-real time Simulation



Control Unit



Control Unit State-Machine Commander



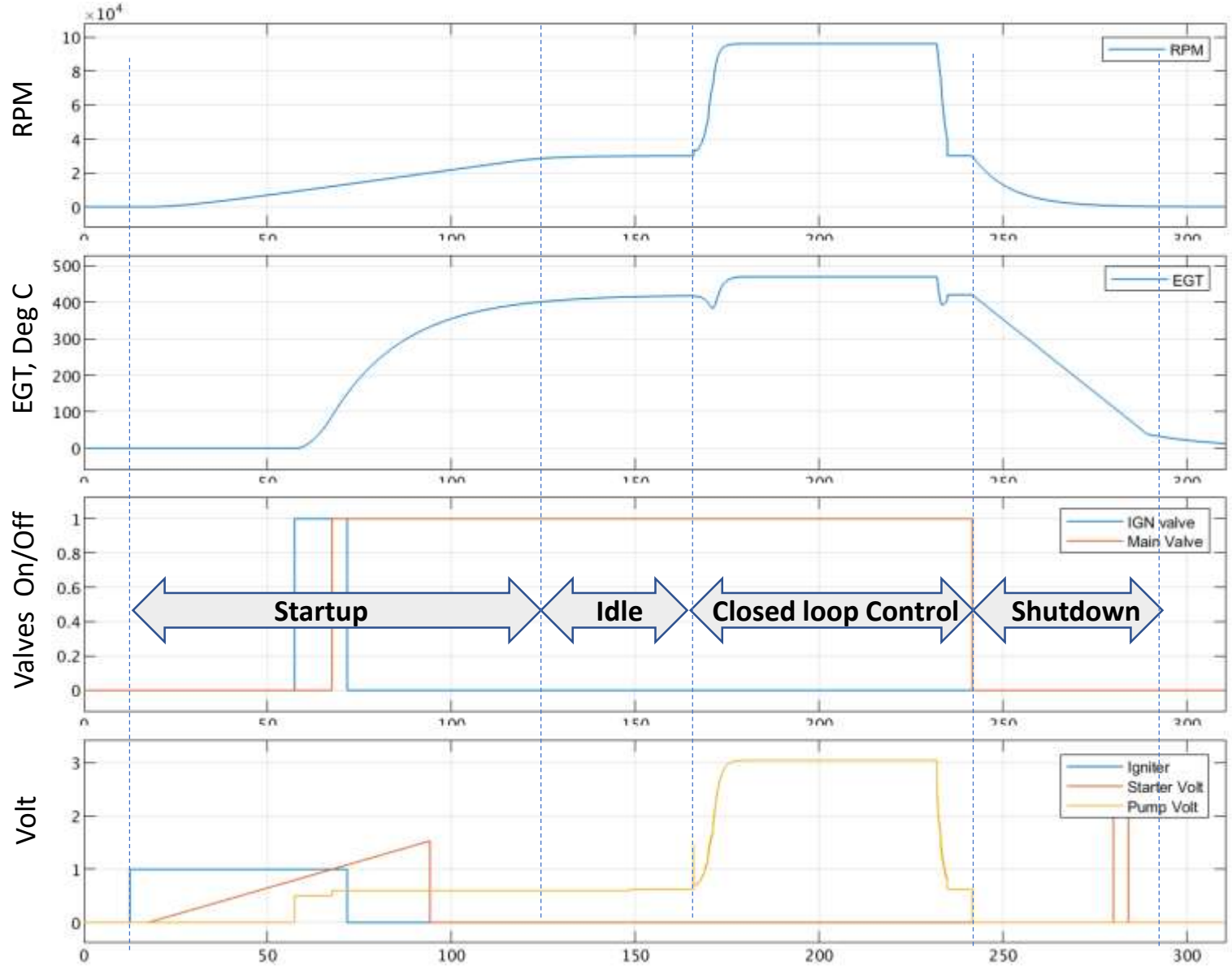
Startup Sequence

(1) Turn on the glowplug and wait <glowplug_interval> seconds.
(2) Gradually increase starter voltage at rate <starter_deriv>.
(2) When rpm > <ignit_rpmth>:
- Open the ignition valve.
- Set the fuel pump voltage to <init_fpv>

(2) When the temperature rises by <init_egt_rise>:
- Open main valve & multiply pump voltage by <fpfactor>
- When the temperature further increases by <egt_rise_2nd>:
  - Close the ignition valve.
  - Turn off the glowplug.

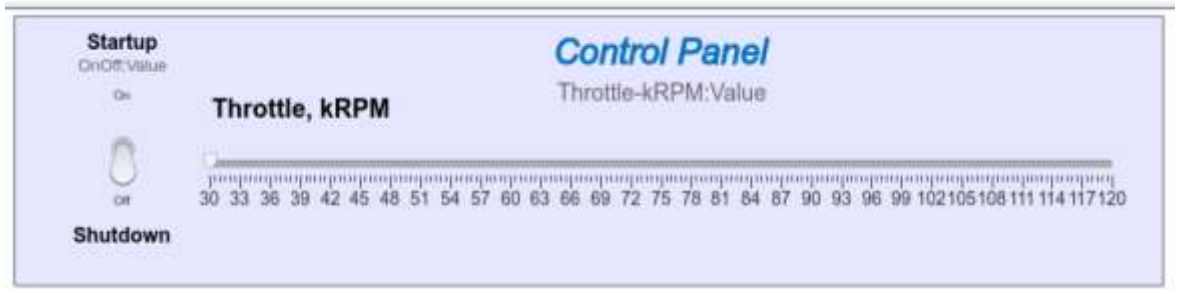
(3) When rpm > <max_starter_rpm> disengage the starter.
(4) When the rpm stabilizes perform calibration.
(5) Get the rpm to idle by changing pump voltage and finish.

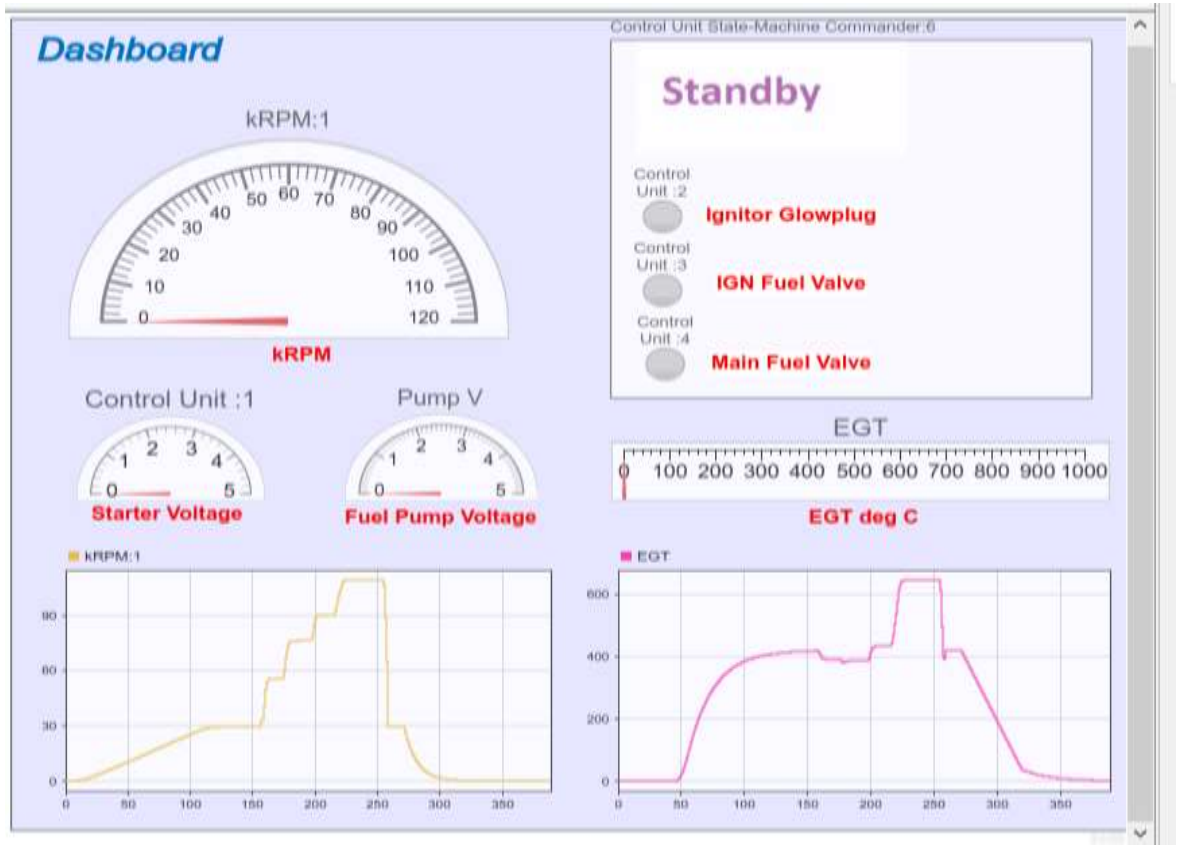
Preliminary Simulation Results

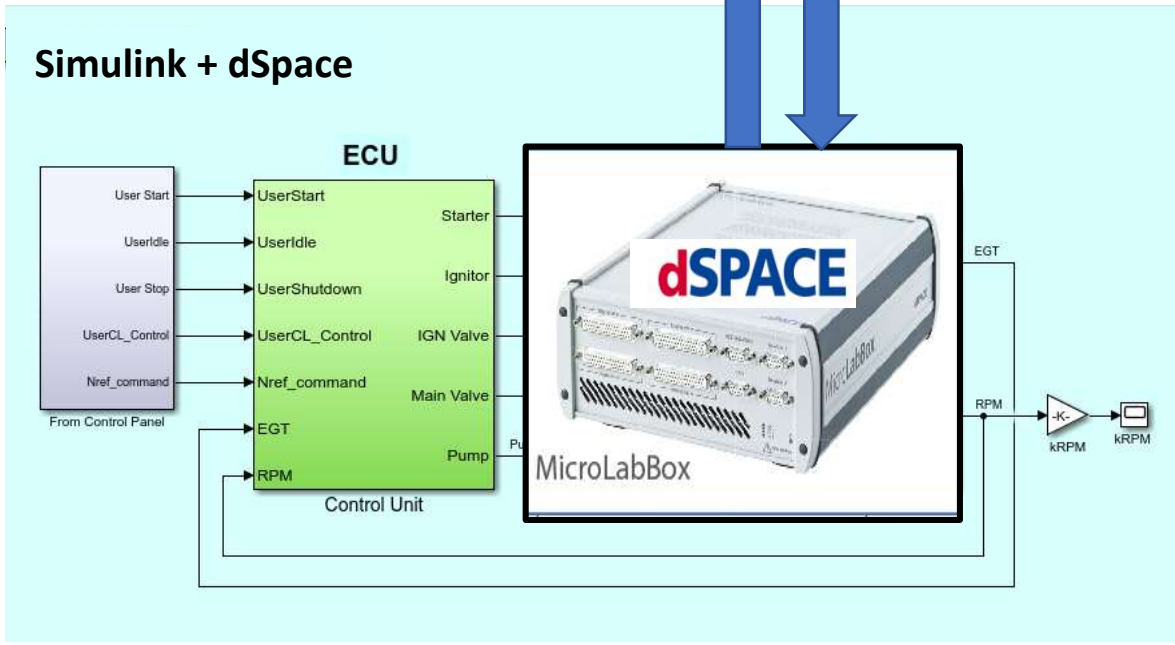


Matlab
Simulink

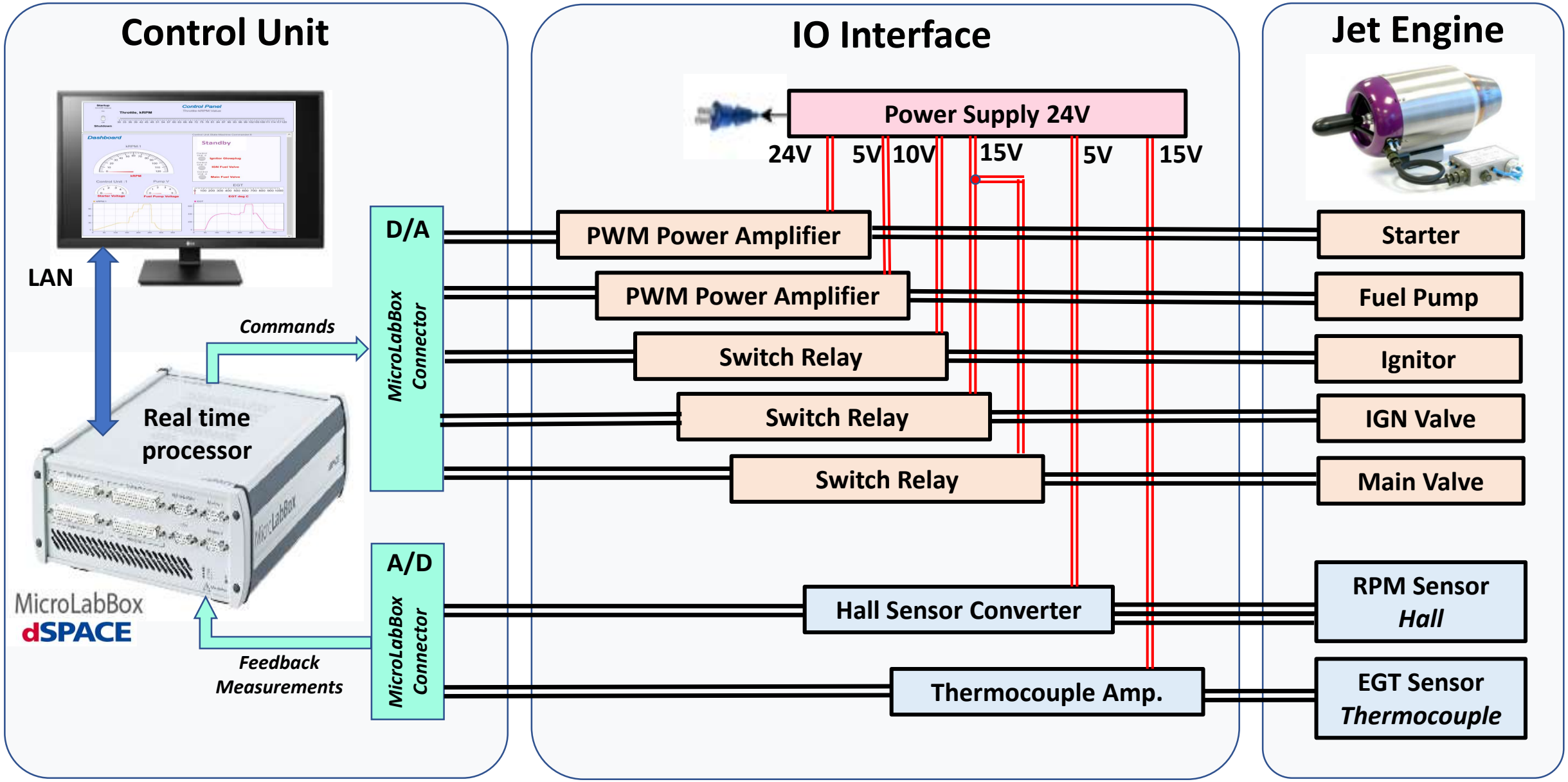
Turbo Jet Engine End-to-end HIL Simulation







Implementation: Wiring Connections Diagram



The Testbed

I/O interface

Olympus micro-turbine Jet Engine

Thank you

for your attention